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INSTITUTE FOR DEFENSE ANALYSES

Proceedings of the NATO Nuclear Human Response Subject Matter Expert Review Meeting 23-25 June 2008 Albuquerque, New Mexico United States of America

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Preston J. Lee
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About This Publication

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PREFACE

This document reports work performed by the Institute for Defense Analyses for the United States Army Office of the Surgeon General in partial fulfillment of the task order CA-6-2281 "Review of NATO AMedP-8 *Planning Guide for the Estimation of Battle Casualties.*" On 23-25 June 2008, a meeting was held in Albuquerque, New Mexico, to reach an international consensus on the nuclear weapon effects human response models to be recommended for use in Allied Medical Publication 8, *NATO Planning Guide for the Estimation of CBRN Casualties* (AMedP-8(C)). Attached are the minutes and presentation slides from that meeting which constitute the record of the proceedings of that meeting.

The authors wish to thank the reviewer, Dr. Jeff Grotte for his careful review of this document, and Mr. Lucas LaViolet who edited this document.

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EXECUTIVE SUMMARY

This paper provides a summary of and briefings from the NATO Nuclear Human Response Subject Matter Expert Review Conference, held at the Defense Nuclear Weapons School, Albuquerque, New Mexico, in June 2008. The purpose of this three-day conference was to review and amend a casualty estimation methodology for exposure to nuclear weapon effects proposed by the Institute for Defense Analyses (IDA) for implementation in a revised version of NATO Allied Medical Publication 8 (AMedP-8(C)). The focus of the conference was on the human response component of the methodology, including severity definitions, appropriate dose/insult ranges, and dose/insult-based physiological system symptom progressions and injury profiles for these effects. During the conference, these elements were discussed and amended to reflect the results of current scientific research and professional opinion expressed by the participants.

This paper begins with a summary of the conference proceedings, followed by the eleven briefings presented at the conference. The first five presentations were designed to familiarize the conference attendees with the purpose of AMedP-8(C) and with the proposed general casualty estimation process. The next four briefings described the technical details of the development and content of the methodology's proposed human response component for nuclear effects, individually and in combination. After these effect-specific briefings, the general casualty estimation and reporting component of the methodology was presented. The final briefing reviewed the consensus points developed by participants during the conference.

This conference was sponsored by the US Army Office of the Surgeon General (OTSG) in its role as the Custodian of AMedP-8.

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I. NATO NUCLEAR WEAPONS SUBJECT MATTER EXPERT HUMAN RESPONSE REVIEW MEETING PROCEEDINGS

A. Purpose:

The purpose of this meeting was to review the proposed human response model for estimating casualty effects resulting from exposure to nuclear insults – irradiation, thermal fluence, and static blast overpressure, focusing in particular on severity definitions and the dose/insult-based injury profiles for the three effects. The model is proposed for potential implementation in NATO Allied Medical Publication 8 (AMedP-8).

B. Attendees:

Canada

- CDR Ian Torrie, Health Services Operations
- Dr. Diana Wilkinson, Defense Research and Development Canada

France

- GEN Yves Chantrelle, French Army Medical Research Center

Germany

- COL Dirk Densow, Bundeswehr Medical Office
- Mr. Steven Hotop, ESG Company Munich
- Mr. Jakob Rieck, ESG Company Munich

Great Britain

- LtCol David Bates, UK Surgeon General
- Dr. David Holt, Consultant to Institute of Naval Medicine
- Dr. Robert Jefferson, Medical Toxicology Center, advisor to Ministry of Defense (MOD)

Netherlands

- Mr. Maarten Huikeshoven, Dutch MOD

United States of America

- COL Craig Adams, Office of the Air Force Surgeon General
- Dr. Carl Curling, Institute for Defense Analyses (IDA)
- Ms. Misouk Choun, US Army Office of the Surgeon General (OTSG)
- Ms. Deena Disraelly, IDA
- SSgt Dixon, Defense Nuclear Weapons School (DNWS)

MAJ Kevin Hart, OTSG

COL Lester Andy Huff, Armed Forces Radiobiological Research Institute (AFRRI)

Mr. Michael Leggeiri, Jr, US Army Medical Research and Material Command

Dr. Gene McClellan, Applied Research Associates (ARA)

COL John Mercier, AFRRI

Dr. Kyle Millage, ARA

Dr. Eric Nelson, Defense Threat Reduction Agency (DTRA)

Mr. Fred Scudiery, DNWS

Mr. James Smith, OTSG

COL Clark Weaver, J-8, Joint Chiefs of Staff, Medical Defense

CAPT Andy Woods, US Navy Bureau of Medicine (BUMED)

TSgt Wright, DNWS

Dr. Robert Zirkle, IDA

C. Meeting Summary:

The following presentations were given:

MAJ Kevin Hart, US Army – Nuclear Objective & Meeting Overview

COL John Mercier, US Army – Invited Presentation

Dr. Carl Curling – General Nuclear Human Response Modeling Concepts

Ms. Deena Disraelly – Nuclear Insult Ranges

Dr. Robert Zirkle – Illustrative Example – Nuclear

Ms. Deena Disraelly – Nuclear Human Response – Irradiation

Dr. Robert Zirkle – Nuclear Human Response – Blast

Dr. Carl Curling – Nuclear Human Response – Thermal

Ms. Deena Disraelly – Nuclear Human Response – Combined

Dr. Carl Curling – Nuclear Casualty Criteria

MAJ Kevin Hart, US Army – Nuclear Review, Conclusions & Way Ahead

D. Areas of Concurrence:

The following areas and topics were concurred on by the Nations during the meeting:

- General points – maintain consistency with chemical and biological models as feasible
    - No modeling of medical intervention
    - No inclusion of battle stress cases
- General modeling concept – human response can be estimated using specified severity levels as represented on injury profiles
    - Nuclear irradiation progressions concurred to with changes
        - US will review additional data, specifically as it applies to Lower GI

    - Blast progressions (Respiratory is dominant system) concurred to with changes
    - Thermal progressions concurred to with changes
- Dose/insult ranges are accepted as presented with the following corrections (updated ranges are presented below in Tables 1 through 3)
    - Radiation: updated ranges: no observable effect (NOE) range upper bound raised from < 0.75 Gy to < 1.25 Gy, first observable effects range now 1.25–3.0 Gy
    - Blast: no corrections
    - Thermal (Thermal Flash Burn Ranges): updated ranges: upper injury severity range lower bound dropped from 40 %BSA to ≥ 30 %BSA; 20–30 %BSA range should include 10% fatalities
- Symptoms systems
    - Blast: Respiratory is the dominant physiological system (neglect other systems)
    - Thermal:
        - Neglect Upper GI system for all ranges
        - Neglect Immune system for ≥ 30 %BSA range
- Symptoms descriptions
    - Remove “signs” from descriptors
    - Modify Immune system symptoms as described
    - Modify Skin (Thermal) system symptoms as described
    - Add “possible micro-hemorrhaging” to Cardiovascular system level 2
- Human response: radiation
    - Calculate time-to-death as a function of dose
        - Utilize Intermediate Dose Program (IDP) methodology (green line)
- Human response: blast
    - Consider dynamic effects (prone-tumbling) in addition to static overpressure effects for estimation of KIA
        - Utilize Drake methodology (as proposed)
- Human response: thermal
    - No additional areas
- Human response: combined
    - Agreement on proposed methodology for combining radiation, blast, and thermal (R-B-T) injury profiles
- Casualty criteria
    - Recommended proposed casualty definitions
    - Recommendations for WIA with R-B-T severity
    - R-B-T injury profiles to be described/graphed in annex to AMedP-8(C)
    - R-B-T system injury progressions to be described/graphed in technical reference manual (TRM)

Dose Range (Gy)	Description
< 1.25	No observable effect in the majority of the population
1.25 – < 3	A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is > 90% unless there are other injuries
3 – < 5.3	Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible death
5.3 – < 8.3	Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries death may occur within 2 weeks
≥ 8.3	Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2 to 3 weeks; with other injuries death may occur within 2 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1 to 2.5 weeks or if other injuries are also present, patients may die within 6 days

Table 1. Radiation Dose Ranges

Insult Range (kPa)	Description
< 50	No observable effect in the majority of the population
50 – < 140	Eardrum rupture in 50%; threshold lung damage; threshold gastrointestinal damage
140 – < 240	Burdening level lung damage in 50%; burdening level tympanic membrane rupture in 90%
240 – < 290	Burdening level lung damage in 90%; lethality in 10%
≥ 290	Lethality in ≥ 50%

Table 2. Static Overpressure Blast Insult Ranges

Insult Range (%BSA)	Description*
< 1	No observable effect in the majority of the population**
1 – < 10	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
10 – < 20	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
20 – < 30	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain; lethality in 10%
≥ 30	Upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia; multiple organ failure; lethality in ≥ 50%

* Estimation of burn lethality is approximate

** <1%BSA may include a larger area of 1st degree burns

Table 3. Thermal Fluence Burn Surface Area Insult Ranges

E. Recommendations/Next Actions:

Based on this meeting, the following additional tasks were recommended:

1. Participants –
    - Provide supporting documentation, studies, & references as available
    - Review Irradiation (Lower GI and Immune particularly), Blast, and Thermal injury progressions with National subject matter experts (SMEs) (responses requested by 22 July 2008)

2. OTSG/IDA –
    - Incorporate comments as provided for revised versions of read-aheads
    - Prepare updated injury progressions and profiles for National reviews
        - Send updated profiles out for review (responses requested by 8 July 2008)
    - Take Thermal (Flash Burn) injury progressions to ISR/USRAIR for review
    - Incorporate National comments as provided for updated profiles
    - Update the dose/insult ranges as discussed
    - Update the system symptom severity descriptions as discussed
    - Update the injury progressions and profiles as noted
    - Notations to be added to document:
        - This document is for use for human response modeling and casualty estimation purposes only; it is not to be used for operational, logistical, or diagnostic purposes.
        - Purpose: Revise the purpose statement to include “casualties *uniquely* occurring”
        - Severity definitions:

        - These severity definitions are to be used for modeling purposes only; they are not to be used for operational classification of personnel in real-world situations
        - Symptoms descriptions proposed for use in AMedP-8(C) are not the same as those used in AMedP-8(A)
    - Insult description: Describe thermal fluence as "flash burn" for clarity of cause and effect
    - Correct skin thickness (from nm to μm)
    - Limitations (Limitations section must be included up front)
        - The physiological systems considered in the modeling of injury progression are not all inclusive and not the sole potential mechanisms for injury; certain additional casualties may occur due to other injuries or injuries to other physiological systems
        - Eye injuries are not included in the physiological systems modeled

F. Meeting Notes: Presentations were given by MAJ Hart, COL Mercier, Dr. Curling, Ms. Disraelly, and Dr. Zirkle.

1. COL Mattox, Commandant of DTRU – Welcome

COL Mattox welcomed participants, noting that he was honored to be in attendance especially because he had served three years on the staff of the Supreme Command, Allied Powers Europe. He discussed the importance of STANAG 2553 and outlined the challenges faced by the participants in helping address the issues raised by nuclear incidents. He closed by thanking participants and wishing them luck with the meeting.

2. MAJ Kevin Hart – Meeting Overview and Objectives, Introduction

MAJ Hart began by outlining the meeting objectives, then briefly outlined the casualty estimation concept and discussed the foundations of NATO's casualty estimation methodologies. The starting point of the human response model follows the outputs described in SD.2 – i.e., the required outputs of a dispersion model, specifically the numbers and location of people, their disposition, the doses and insults they are exposed to. He pointed out that there are several assumptions and constraints associated with the models and that keeping these in mind over the coming days would be important.

He discussed the development process and the potential process for implementation. He anticipated that for NATO planning purposes, there would be a requirement to work with the people currently working on SABERS or MEDIC to build an implementation capability.

The stated purpose of the document is for medical planners to get what information they need: medical casualties and battlefield effects, resources, etc. If the document can be used for other purposes as well, all the better, but really the end-state customer is the medical planner.

He closed by reviewing the meeting agenda.

3. COL John Mercier, US Army – Invited Presentation – Human Response to Nuclear Weapons: Hiroshima as a Case Study

COL Mercier was invited to present his work studying human response to the nuclear events in Hiroshima. He began by describing the scenario – 16 KT air burst with essentially no fallout and 255,000 people. Although he pointed out that the casualty estimates are largely dependent on which report is being read, approximately half of the population became casualties and approximately half of the casualties were fatalities, a large fraction of whom died within the first few days. A large fraction of hospitals was destroyed, and doctors and nurses became casualties themselves.

He showed pictures of the affected regions both before and after detonation, and described the devastation. He also examined regions where people were saved by shadowing or other protective effects.

He then described the quantitative definitions and methods of injury resulting from each of the primary insults. He further suggested that translational effects could potentially be estimated using modern-day data (i.e., motorcycle accidents, etc). He then detailed the methodology for estimating casualties currently used in the combined injury program (i.e., performance-based estimations).

Questions by participants included:

- Had any of the people in Hiroshima been bombed before?
    - No. That was one of the strategies, to leave a couple cities untouched to prove the bomb. Tokyo was fair game – there were more deaths from incendiary bombings than in Hiroshima.
- Do you know what fraction died of secondary infection?
    - Malnutrition was an issue even before the bombing. Following infections, almost all of the 2nd and 3rd degree burns became infected, but most of those survived.

Participants suggested that policy consideration and other factors—including lack of food, water, and shelter—determined the final fatality values and may have resulted in overestimations of the direct-effect nuclear fatalities.

4. Dr. Carl Curling – General Nuclear Human Response Modeling Concept

Dr. Curling laid the foundation for the remainder of the meeting, describing the development of the AMedP-8 SD.3 document, the general human response modeling concept proposed for use in the document, associated definitions, model assumptions, and model limitations. The proposed human response models are described by injury profile maps – based on an explanation of symptoms severities over time, which are combined to build injury progression maps. The objective of the document is to estimate the status over time of some personnel exposed to some CBRN agent. To focus on nuclear, it is the number of people who are expected to be wounded or killed as a result of radiation dose and/or blast or thermal insult.

The model does not look at certain medical casualties – those who are psychological casualties although they may be expected to seek medical assistance or those who died or are injured as a result of secondary effects.

Questions by participants included:

- Why are we concerned with people who are being killed? As a doctor, I lose interest in my patients once they die unless they'll result in a lot of paperwork. Who will use this?
    - It's a requirement per AJP 4-10. AJP 4-10 says you will report out killed in action (KIA), wounded in action (WIA), and died of wounds (DOW). Where it comes in for the medical planner, it's part of the risk assessment/decision-making process.
- Is the assumption of no medical treatment consistent with the chemical and biological models?
    - Yes.
- What's the conversion from psi to kPa?
    - 6.89 kPa to 1 psi.
- With mild severity, could you have a degradation of your ability to perform your tasks?
    - Certainly. Severity definitions are ambiguous, but it's unclear how severe the injury is or how long the personnel are lost for.
- Are you using these numbers purely for the modeling purposes?
    - Yes. They are only intended for modeling purpose.
- Are we counting injuries from collapsed buildings?
    - That falls into the category of higher-order effects. While some of these higher-order effects might be examined, building collapse is not one of them.
- What are higher-order effects?
    - Secondary (missiling), tertiary (whole-body translation), quaternary (building collapse, etc.)…
- What is thermal fluence?
    - Radiant energy in cal/cm^2 or J/cm^2.
- Can we be assured that the planners will be told to look elsewhere for guidance on battle stress cases (BSCs), and others?
    - We can certainly put that in the document.
- Would it be prudent to put something in to say that planners should account for some additional percentage of casualties due to effects not modeled?
    - MAJ Hart suggest that it should go into AMedP-7 as the capstone document; we can put it in here as well.

Participants indicated that it may be possible to standardize medical care for incorporation at a later time based on the forthcoming revision of AMedP-6.

Participants discussed the importance of battle stress cases and the possible problems posed by neglecting these. These have been excluded for bio and chemical agents; in order to be consistent, they will not be modeled for nuclear or radiological events.

Participants discussed additional symptoms that might need to be included, and suggested erythemic and neurological effects following irradiation exposure as examples. Dr. Curling pointed out that the model does consider cerebrovascular symptoms and that by the time neurovascular symptoms manifest themselves, other physiological effects have caused the individual to seek medical attention.

Participants suggested that they would anticipate respiratory symptoms following thermal exposure. The researchers indicated that data do not exist to support the inclusion of respiratory effects from burns except in the case of flame burns which are not considered as prompt nuclear effects but rather as secondary effects.

Participants expressed concerns that modeling definitions could be confused with triage categories. MAJ Hart indicated that the only way such confusion could arise would be if the NATO tool requires output in triage categories. Participants requested that a note be included that the profiles and definitions are only to be used for presumptive modeling purposes.

Participants then continued discussing the definitions, asking whether legal definitions should be included. There was disagreement regarding whether tumbling, missiling, and other effects are direct or indirect effects.

Participants raised concerns about the utility of a document that had significant limitations, particularly as battle stress cases may be a significant fraction of the total casualties. The concern is that there may not be a good way to implement many of these issues. Participants suggested that the impact may be scenario dependent; cohesiveness of the unit has a huge impact on the psychological effects.

5. Ms. Deena Disraelly – Nuclear Insult Ranges

Ms. Disraelly discussed the nuclear insult ranges for irradiation, static blast overpressure, and thermal fluence, as well as the derivation of the ranges and the burn surface area calculation.

Questions by participants included:

- How do we get to 12% bare skin from hands and face?
    - It's not clear how this number was determined, but possibly derived assuming that shirt sleeves were rolled up.

Participants suggested that at less than 2 Gy, individuals are not expected to need medical care.

Participants requested to revisit the irradiation ranges during the human response brief. Participants additionally requested to change the thermal fluence ranges; they suggested collapsing the 30–40% burn surface area and >40% burn surface area bands; move 10% fatality to 20–30% band.

Participants also discussed uniform type and whether it was necessary to include that factor. Ms. Disraelly explained that a new threshold value could be entered into the calculation to account for different uniforms.

6. Dr. Robert Zirkle – Illustrative Example – Nuclear

Dr. Zirkle walked through an illustrative example, describing the series of clinically differentiable dosage bands, each of which has signs/symptoms dosage maps associated with it, as well as the injury profile map which gives an overall example of how disease severity changes over time. Further, there are criteria set by the user which describe the personnel status and the times under consideration – i.e., time to reach a medical treatment facility, evaluative time period, reporting time, total time, etc. The inputs are exposures, and the estimation of casualties follows a process to determine KIA, WIA, and DOW as applicable. Additionally, he walked through a number of specific examples to demonstrate how the model works.

7. Ms. Deena Disraelly – Nuclear Human Response – Irradiation

Ms. Disraelly reviewed the nuclear irradiation model assumptions and then presented the symptoms, as well as the symptoms progressions and overall injury profiles over time for the irradiation human response model. Additionally she discussed methods for incorporating time-to-death as a function of radiation dose.

Questions by participants included:

- At some point, are we going to capture all the gaps or model limitations in one place?
    - In the document, we would note all the limitations.
- Are we complicating things by having Upper GI and Lower GI – why both?
    - Combined methodology broke them out this way (Upper GI and Lower GI); symptoms manifested in these two systems – don't track at same time or achieve same level of severity. Separating allows us to map symptoms (nausea/vomiting and diarrhea) separately.
- Don't all the data include persons who have been treated?
    - No, not all cases; some are and some are not. In Hiroshima and Nagasaki, for example, radiation injuries simply received primitive care.
    - Additionally, the IDP data did not include the "School" data from Hiroshima. The widespread applicability of the school data, however, has been questioned because of its specific concentration of young females.
- Is there any reason to go over 100 Gy?
    - No reason, as the individual has already been turned to ashes by that point. This value was included in the graphs simply to compare with the tail of the Upton Curve; no reason to represent it in the document.

Participants discussed time-to-death methodologies. One participant indicated that Radiation-Induced Performance Decrement (RIPD) was used to determine, if a person is going to die, the time at which they die; it had not been used to predict whether a person dies. Participants suggested that the IDP equation was simpler and seemed to be correct.

Participants expressed concern that the time-to-death equation might eventually be incorporated into AMedP-6; researchers assured that this was not the intent.

Participants concurred that the IDP method of calculating time-to-death was a reasonable approximation for incorporation into the proposed methodology.

8. Dr. Robert Zirkle – Nuclear Human Response – Blast

Dr. Zirkle reviewed the nuclear blast model assumptions and then presented the symptoms, as well as the symptoms progressions and overall injury profiles over time for the blast human response model. The proposed model currently focuses on static overpressure effects. Additionally, however, he discussed methods for potentially incorporating higher order effects (i.e., whole body translation) and the resulting injury and lethality curves. He discussed the issues associated with incorporating this method of injury – orientation, yield dependence, environment, angle of impact, etc, then proposed a methodology for incorporating a prompt lethality curve.

Questions by participants included:

- What's the conversion factor from psi to kPa?
    - 6.89 kPa to 1 psi.
- How would this fit into the concept that we've been discussing?
    - It fits with respect to how time-to-death is calculated for radiation and may change the estimate of KIA.
- What this is saying is at a low yield, you need a high blast overpressure to get a sufficient dynamic pressure? What's happening with radiation and thermal?
    - Below 3KT, radiation is dominant; above 3KT, radiation drops off quickly. KIA alone would underestimate casualties.

Participants discussed the utility of incorporating translational effects and how they should be incorporated if the group determined that the proposed methodology for doing so was the correct approach. Many participants recommended leaving it out. The final consensus of the group, however, was to include only the lethalities as a function of an initially prone posture and decelerative tumbling so as not to underestimate KIAs.

Participants also agreed that lung injury was the primary physiological mechanism for blast injury.

9. Dr. Carl Curling – Nuclear Human Response – Thermal

Dr. Curling reviewed the nuclear thermal fluence model assumptions and then presented the symptoms, as well as the symptoms progressions and overall injury profiles over time for the thermal fluence human response model.

Questions by participants included:

- If you introduce electrolyte imbalance – this is definitely a sign; so why not include granulocytosis and lymphopenia into radiation?

- This is just a descriptor of the injury, not injury profile representations.

Participants indicated that there are eye, face and hand concerns. The only thing to do in those cases is to intubate to protect the airway from obstruction. This table is for whole body; if you have >20% burns, some of this will concern the face.

Participants recommended using flash burn vice thermal insult range; removing thermal insult mitigates confusion about the combination of flash and flame burns. Later in the discussion, participants concurred with using the phrase "thermal fluence."

Participants discussed the impact of burns on hands and eyes as observed in Hiroshima victims; others indicated that some effects were due to pre-existing conditions of starvation and malnutrition which impacted the injury manifestations.

Participants discussed burn progression; there was some disagreement among participants about whether second degree burns could progress to third degree burns if left untreated. The US delegation suggested that burn injury profiles be reviewed and modified by burn experts and then resubmitted to the Nations for comment.

Participants recommended removing "partial thickness" from the description of "mild" skin burns. They suggested that a second degree burn is not going to be self-care; rather, the patient will go into the medical system and stay until the burn is healed.

Participants recommended the removal of the Upper GI physiological system from the thermal "flash burn" model.

Participants discussed the symptom progressions and injury profile maps in detail and made recommendations for changes.

10. Ms. Deena Disraelly – Nuclear Human Response – Combined

Ms. Disraelly reviewed the nuclear combined model assumptions and then presented the symptoms, as well as the methodologies for combining irradiation, blast, and thermal fluence injury profile maps to estimate the human response. She reviewed the updated dose and insult ranges, incorporating the recommended changes.

Participants concurred on the presented dose and insult ranges and descriptions.

Participants again discussed that they would like the opportunity to have National burn experts review the thermal fluence symptom progressions and injury profiles and would provide comments.

11. Dr. Carl Curling – Nuclear Casualty Criteria

Dr. Curling presented the methodology for using injury profile maps to estimate casualties and other personnel status and discussed multiple levels of detail that could be

considered. He recommended the specification of casualties by insult and severity level (i.e., mild radiation injury with moderate blast injury) at time of casualty presentation.

Questions by participants included:

- How does the planner calculate the number of casualties?
    - Casualties are summed.
- You're assuming that for each icon, each person in that icon gets the same exposures, at least for planning purposes?
    - That's true, although the calculation of shielding can alter that.
- It's unclear why you feel the necessity to reduce the output at this point in time when we haven't described the user interface. Why are we making this decision now rather than at time of implementation?
    - We could write the document to the minimum standard and that is certainly a reasonable suggestion. We were trying to come up with the most reasonable suggestion – the base rate and the types of injuries. We want to include the information the planners need to make their estimate without information they don't.
- How will the symptom progressions be provided in the technical reference manual?
    - We will provide the minimum amount needed to draw the curves (reference points), but tables will be available to MAJ Hart.
- I assume the TRM will be available to those who participate in the process.
    - Of course. MAJ Hart intends to make it available but does not want to run it through a standardization process.

Participants requested that underlying symptom progressions be available even if not directly in the document. Progressions will be made available in the annex of the document or in the technical reference manual.

Participants concurred with inclusion of RBT injury profiles in annex and recommended including WIA with RBT severity. They also requested symptom progressions be included in the technical reference manual.

12. MAJ Kevin Hart – Nuclear Review, Conclusions and Way Ahead

MAJ Hart concluded the meeting by thanking participants and reviewing the areas of concurrence and taskings. (The areas of concurrence and the taskings are listed earlier in this memo.)

The updated injury profiles and their underlying symptom progressions, with recommended changes incorporated, which were concurred to by the meeting participants, are shown in Figures 1 through 40 below. After approximately 100 hours, the time-component portion of the profiles should be neglected for doses in excess of 5 Gy as indicated by the "SS" marks on the injury profiles. Profiles should be followed up to the calculated time-to-death. KIA or DOW due to whole-body radiation dose should be determined by time-to-death calculations only.

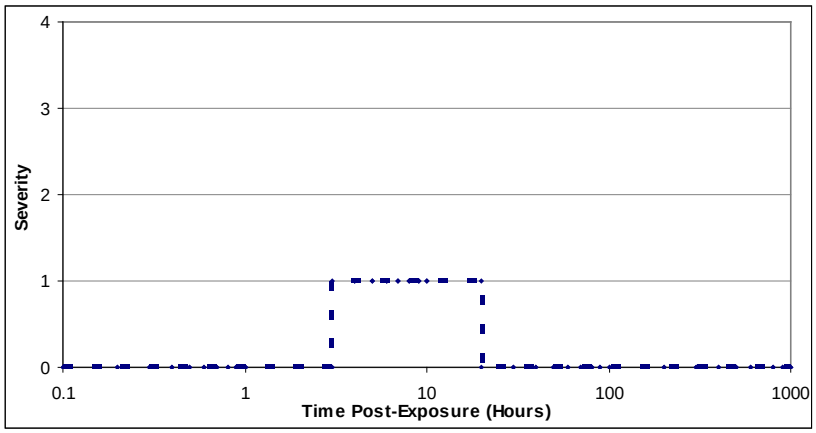

Figure 1. Upper GI Symptom Progression for Whole-Body Radiation Dose Range 1.25 – < 3 Gy

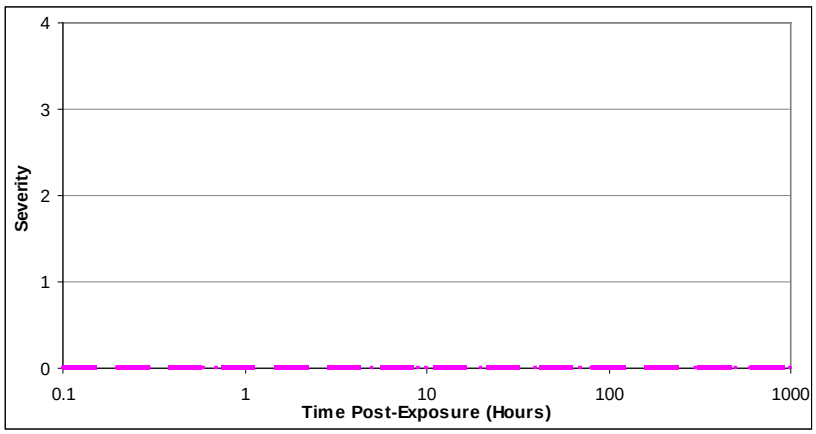

Figure 2. Lower GI Symptom Progression for Whole-Body Radiation Dose Range 1.25 – < 3 Gy

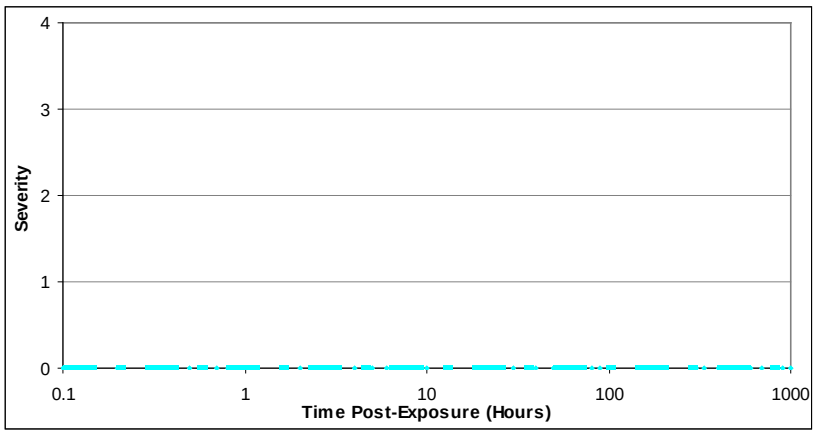

Figure 3. Cardiovascular Symptom Progression for Whole-Body Radiation Dose Range 1.25 – < 3 Gy

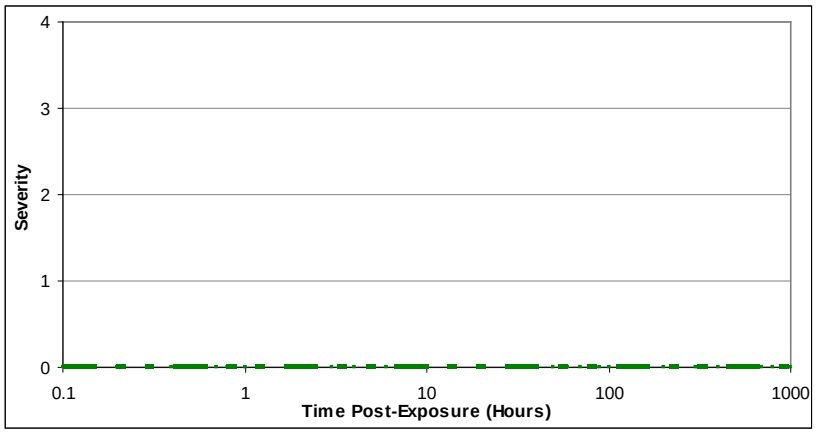

Figure 4. Immune Symptom Progression for Whole-Body Radiation Dose Range 1.25 – < 3 Gy

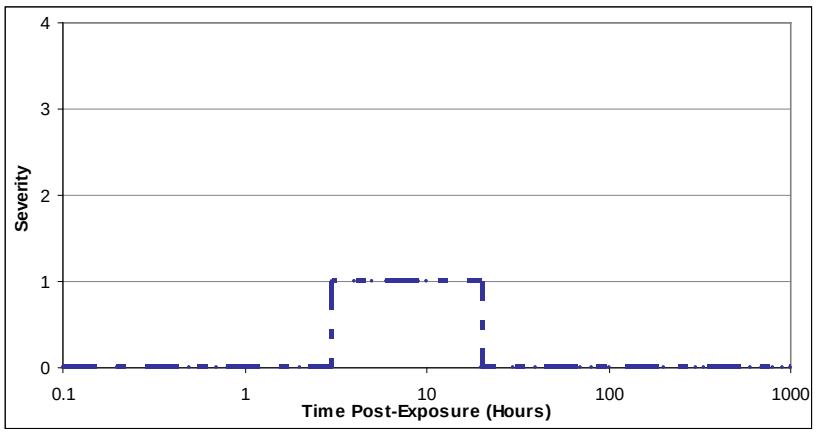

Figure 5. Injury Profile for Whole-Body Radiation Dose Range 1.25 – < 3 Gy

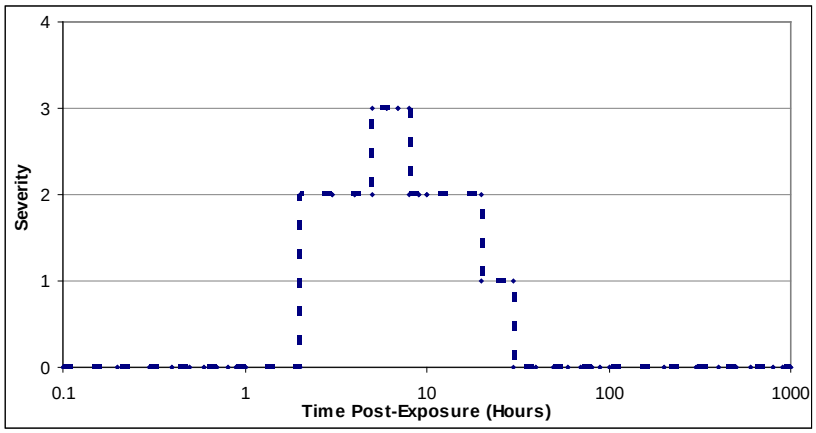

Figure 6. Upper GI Symptom Progression for Whole-Body Radiation Dose Range 3 – < 5.3 Gy

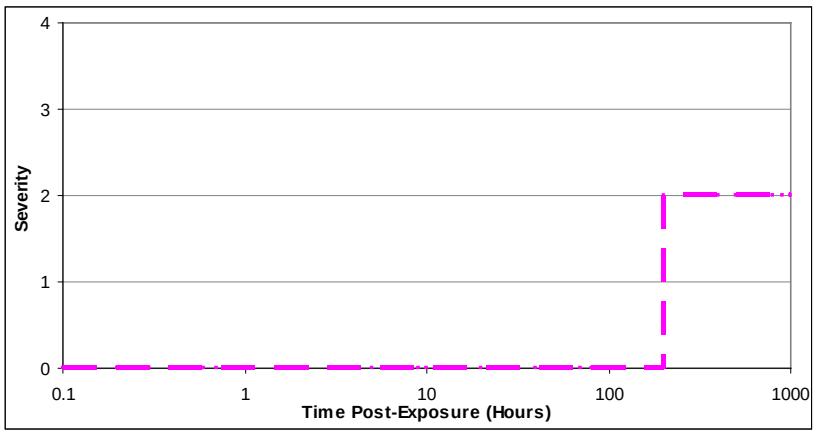

Figure 7. Lower GI Symptom Progression for Whole-Body Radiation Dose Range 3 – < 5.3 Gy

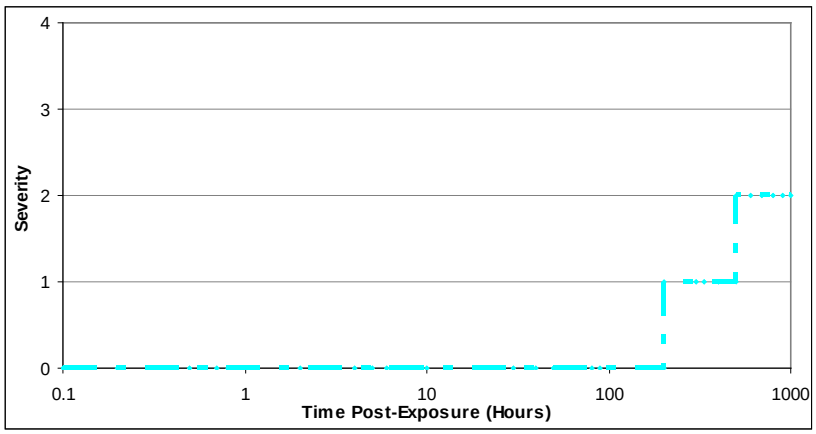

Figure 8. Cardiovascular Symptom Progression for Whole-Body Radiation Dose Range 3 – < 5.3 Gy

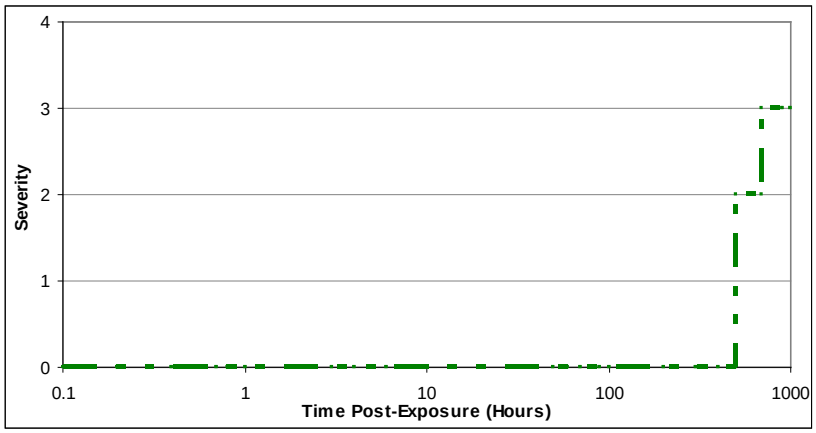

Figure 9. Immune Symptom Progression for Whole-Body Radiation Dose Range 3 – < 5.3 Gy

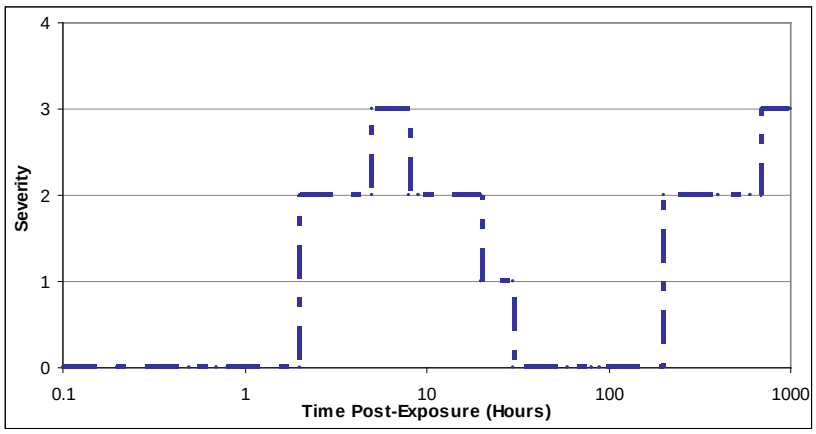

Figure 10. Injury Profile for Whole-Body Radiation Dose Range 3 – < 5.3 Gy

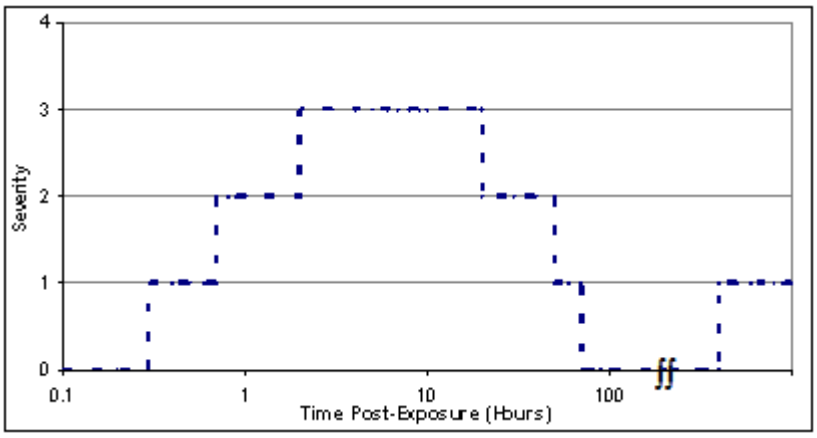

Figure 11. Upper GI Symptom Progression for Whole-Body Radiation Dose Range 5.3 – < 8.3 Gy

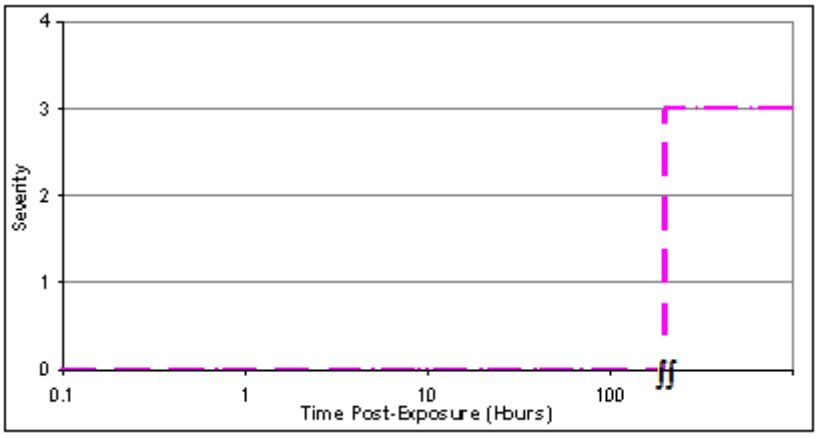

Figure 12. Lower GI Symptom Progression for Whole-Body Radiation Dose Range 5.3 – < 8.3 Gy

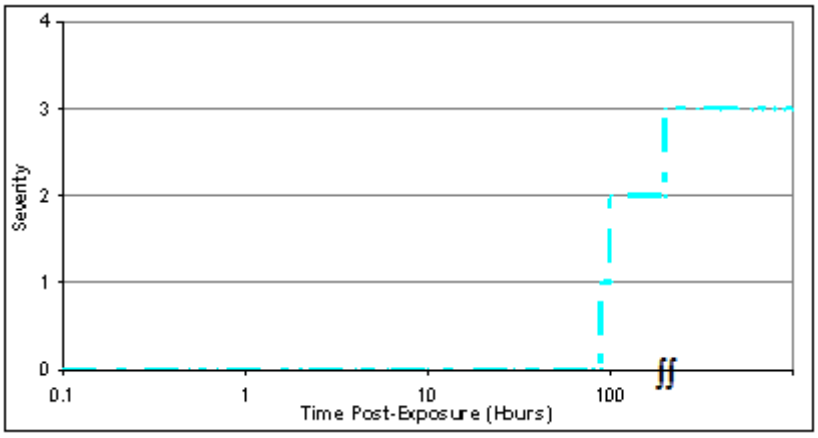

Figure 13. Cardiovascular Symptom Progression for Whole-Body Radiation Dose Range 5.3 – < 8.3 Gy

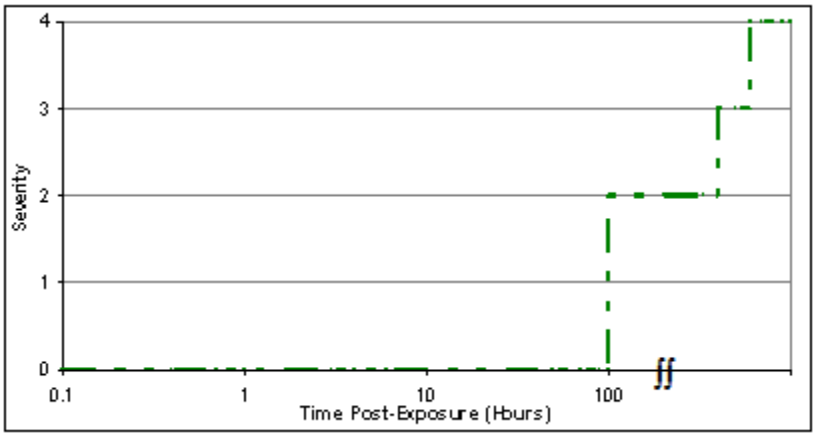

Figure 14. Immune Symptom Progression for Whole-Body Radiation Dose Range 5.3 – < 8.3 Gy

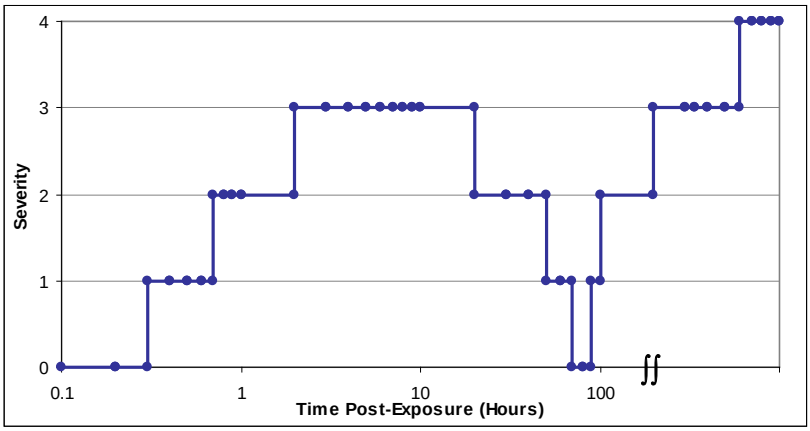

Figure 15. Injury Profile for Whole-Body Radiation Dose Range 5.3 – < 8.3 Gy

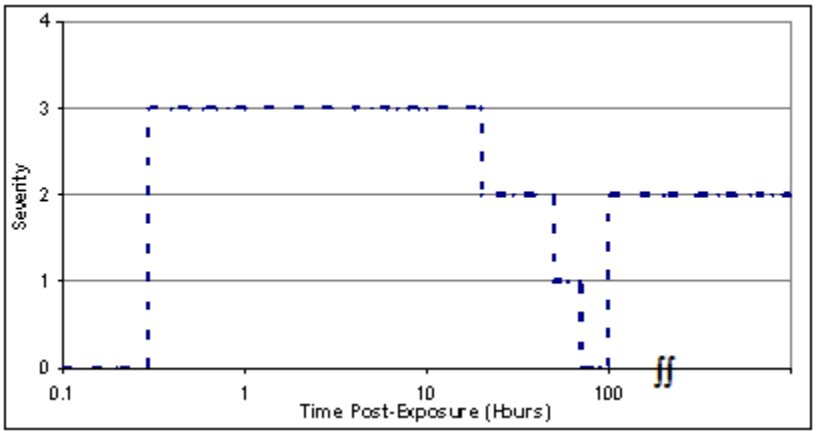

Figure 16. Upper GI Symptom Progression for Whole-Body Radiation Dose Range ≥ 8.3 Gy

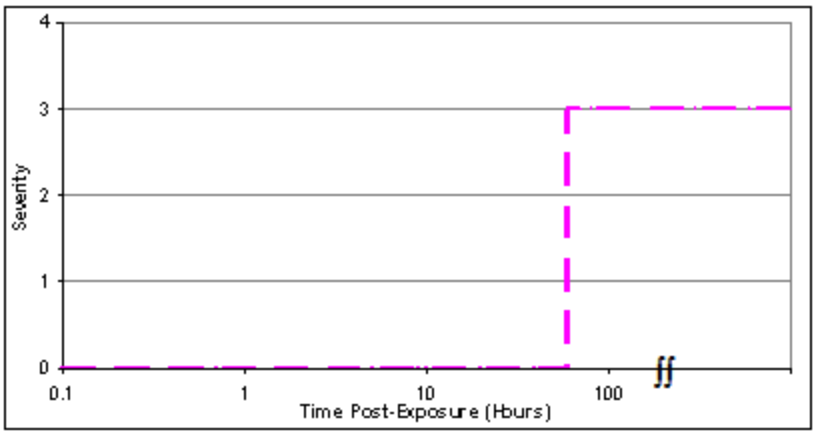

Figure 17. Lower GI Symptom Progression for Whole-Body Radiation Dose Range ≥ 8.3 Gy

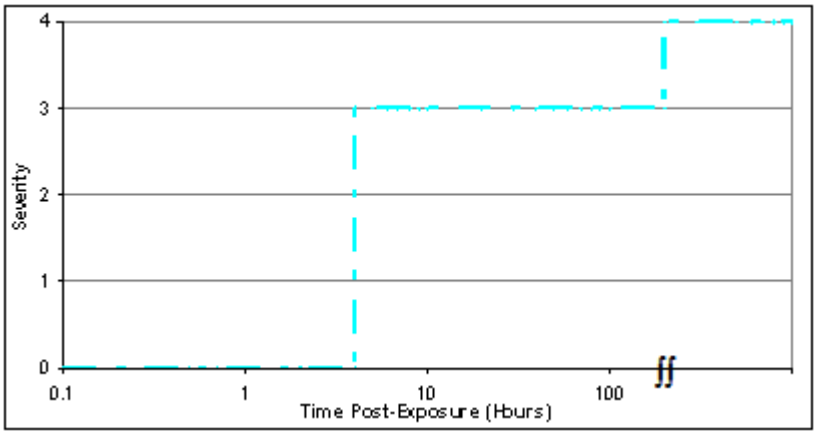

Figure 18. Cardiovascular Symptom Progression for Whole-Body Radiation Dose Range ≥ 8.3 Gy

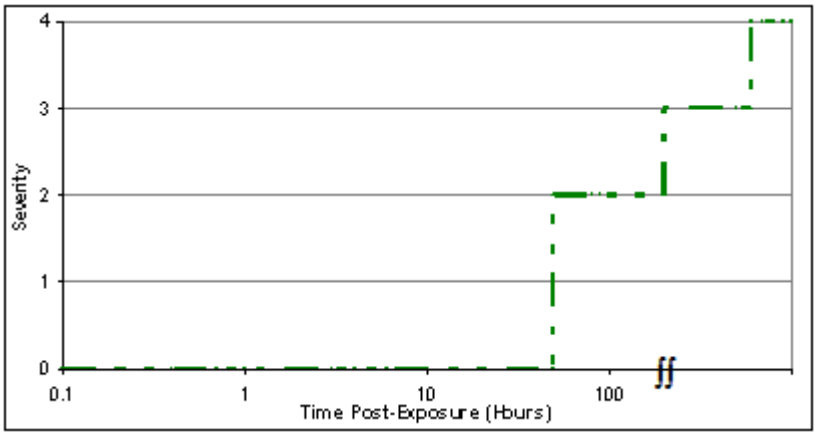

Figure 19. Immune Symptom Progression for Whole-Body Radiation Dose Range ≥ 8.3 Gy

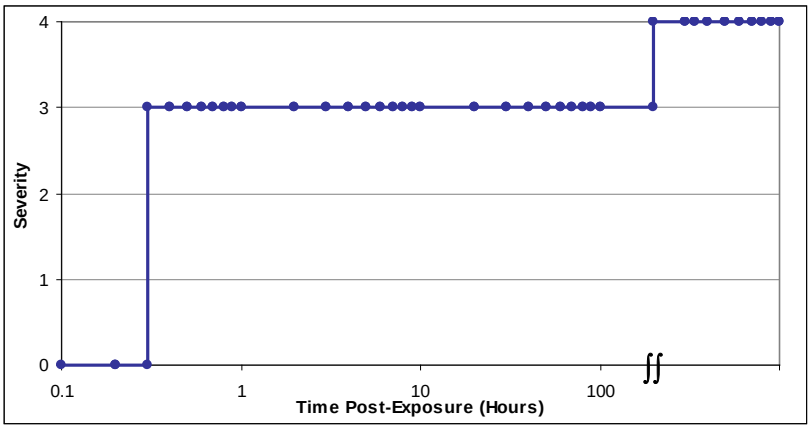

Figure 20. Injury Profile for Whole-Body Radiation Dose Range ≥ 8.3 Gy

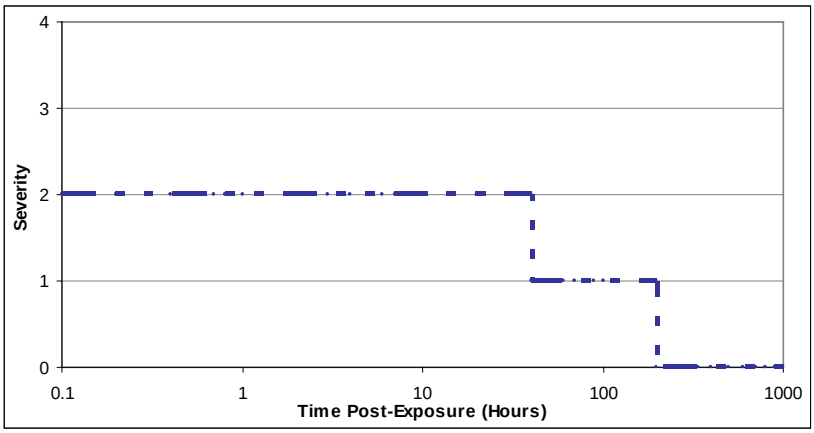

Figure 21. Injury Profile for Blast Insult Range 50 - < 140 kPa*

*Blast injury profile follows the Respiratory symptom progression.

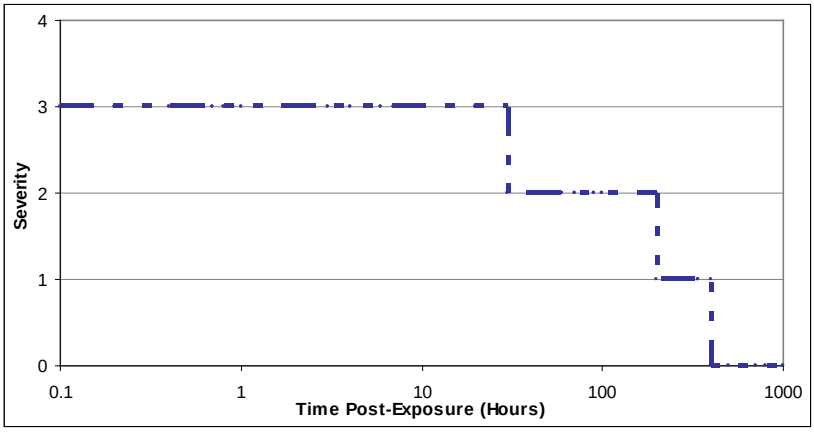

Figure 22. Injury Profile for Blast Insult Range 140 - < 240 kPa*

*Blast injury profile follows the Respiratory symptom progression.

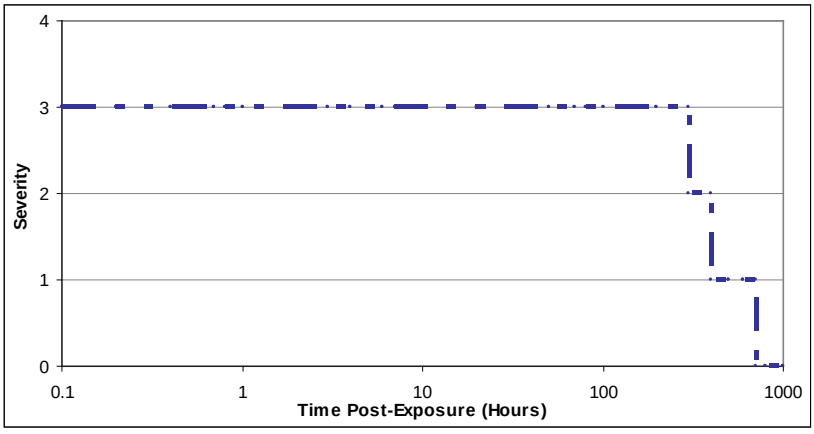

Figure 23. Injury Profile for Blast Insult Range 240 - < 290 kPa*

*Blast injury profile follows the Respiratory symptom progression.

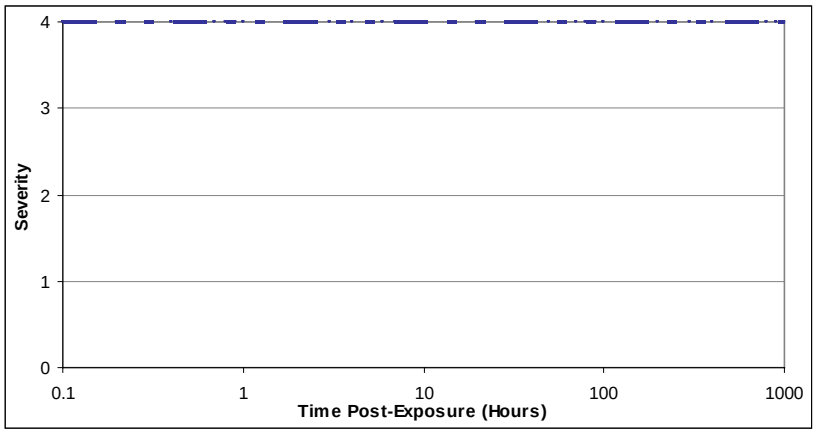

Figure 24. Injury Profile for Blast Insult Range ≥ 290 kPa*

*Blast injury profile follows the Respiratory symptom progression.

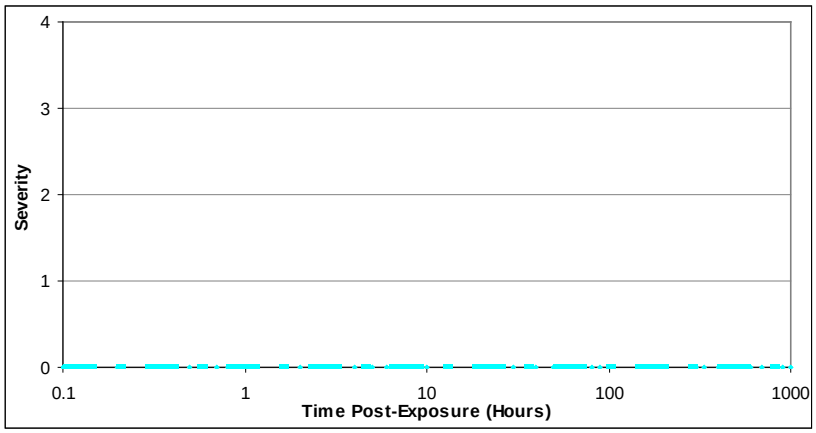

Figure 25. Cardiovascular Symptom Progression for Thermal Insult Range 1 - < 10 %BSA

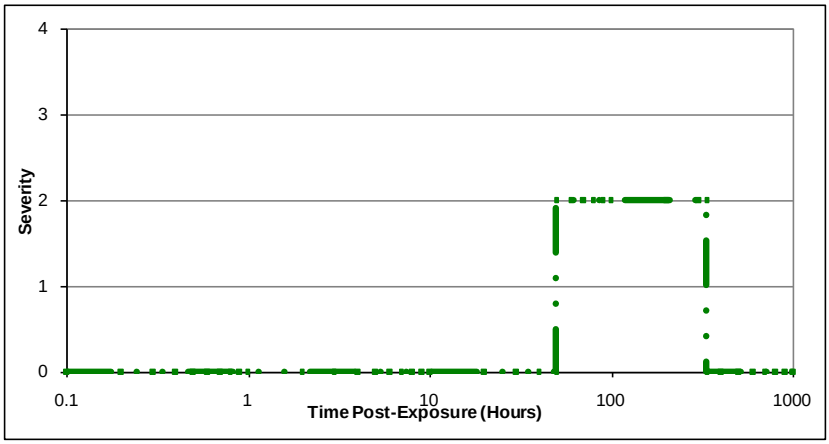

Figure 26. Immune Symptom Progression for Thermal Insult Range 1 - < 10 %BSA

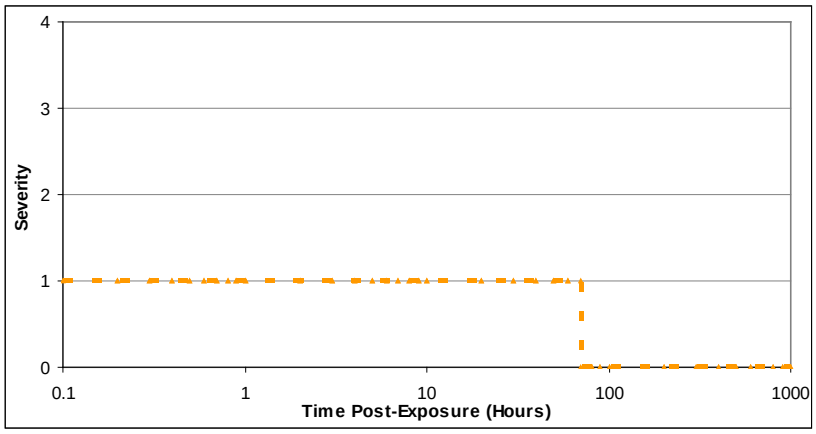

Figure 27. Skin Symptom Progression for Thermal Insult Range 1 - < 10 %BSA

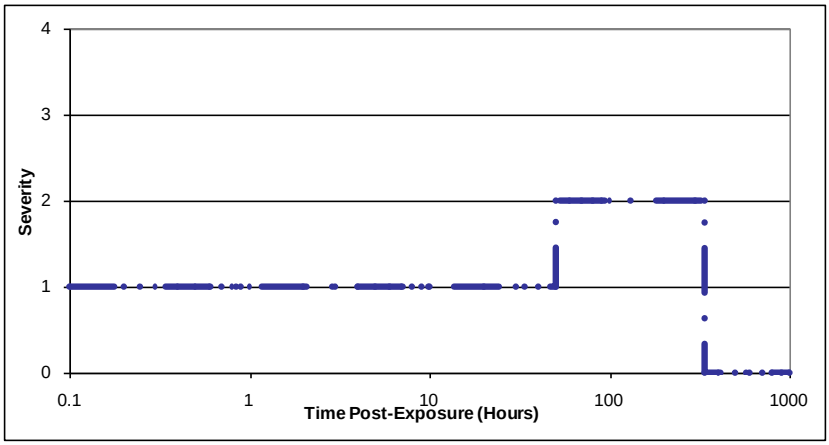

Figure 28. Injury Profile for
Thermal Insult Range 1 - < 10 %BSA

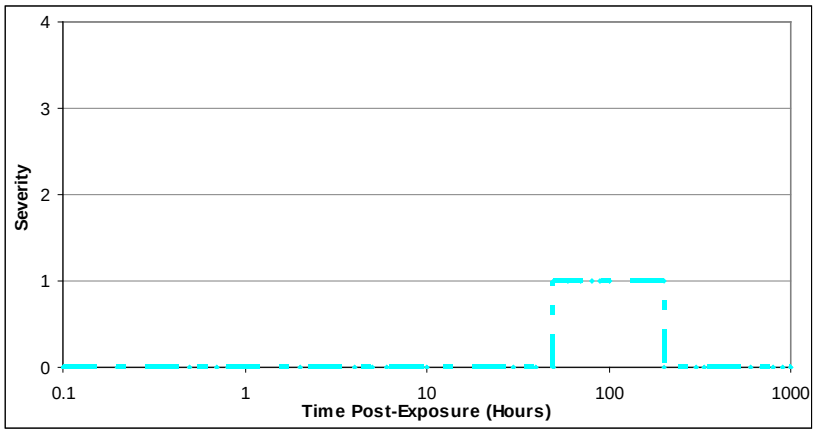

Figure 29. Cardiovascular Symptom Progression for Thermal Insult Range 10 - < 20 %BSA

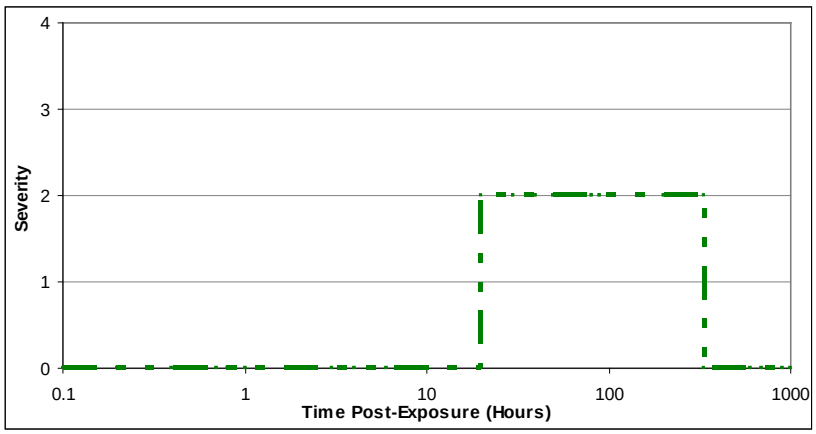

Figure 30. Immune Symptom Progression for Thermal Insult Range 10 - < 20 %BSA

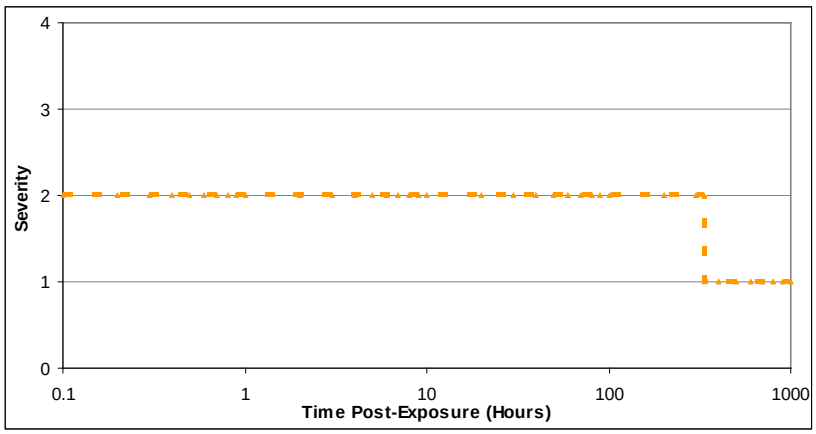

Figure 31. Skin Symptom Progression for Thermal Insult Range 10 - < 20 %BSA

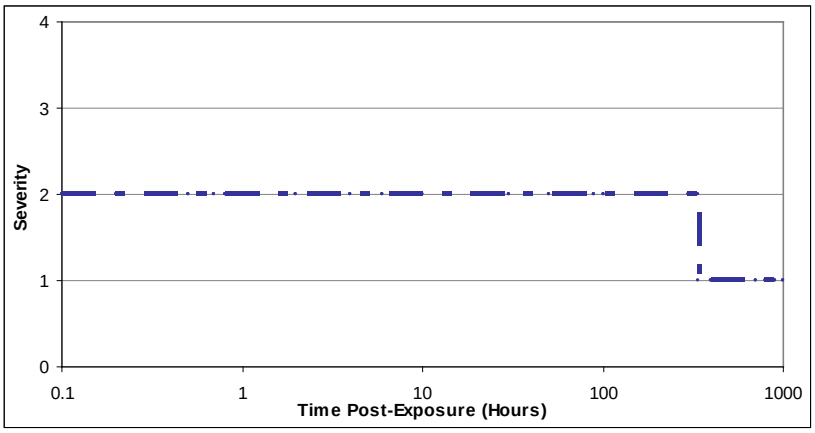

Figure 32. Injury Profile for
Thermal Insult Range 10 - < 20 %BSA

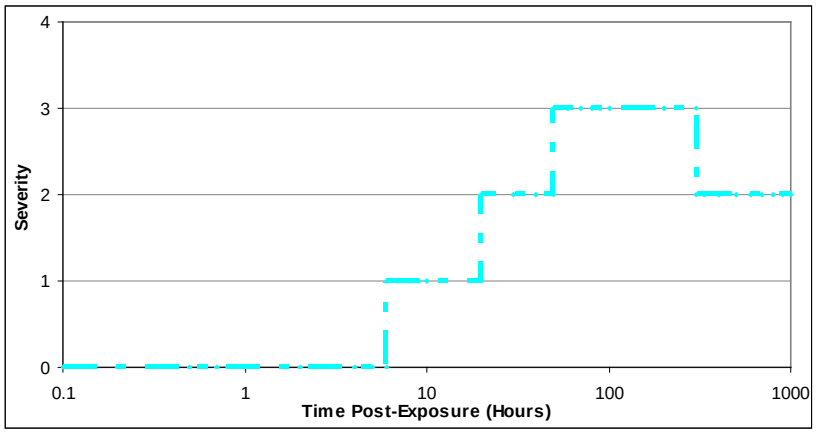

Figure 33. Cardiovascular Symptom Progression for Thermal Insult Range 20 - < 30 %BSA

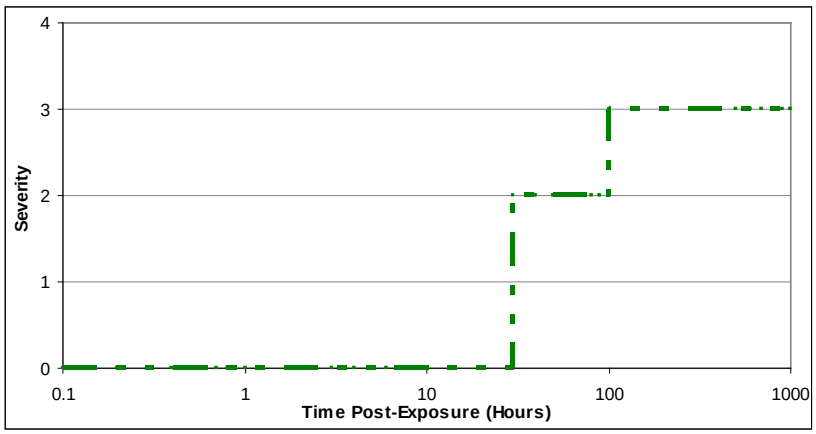

Figure 34. Immune Symptom Progression for Thermal Insult Range 20 - < 30 %BSA

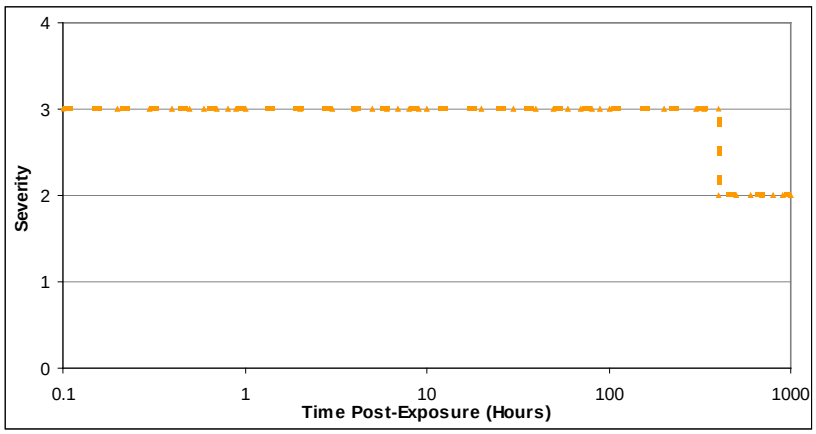

Figure 35. Skin Symptom Progression for Thermal Insult Range 20 - < 30 %BSA

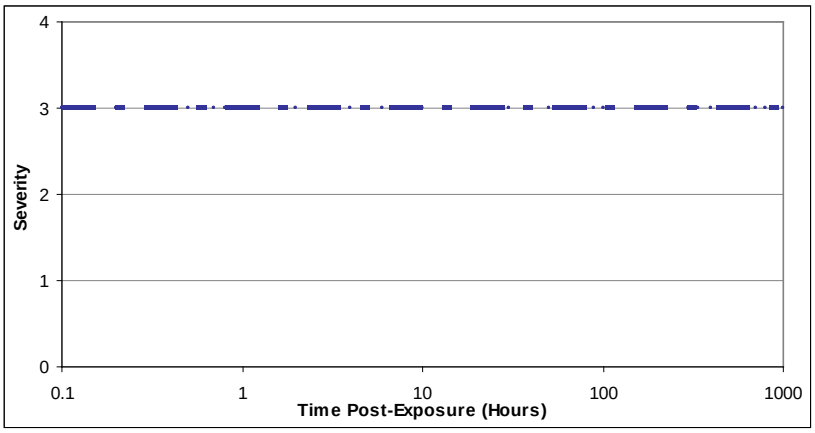

Figure 36. Injury Profile for
Thermal Insult Range 20 - < 30 %BSA

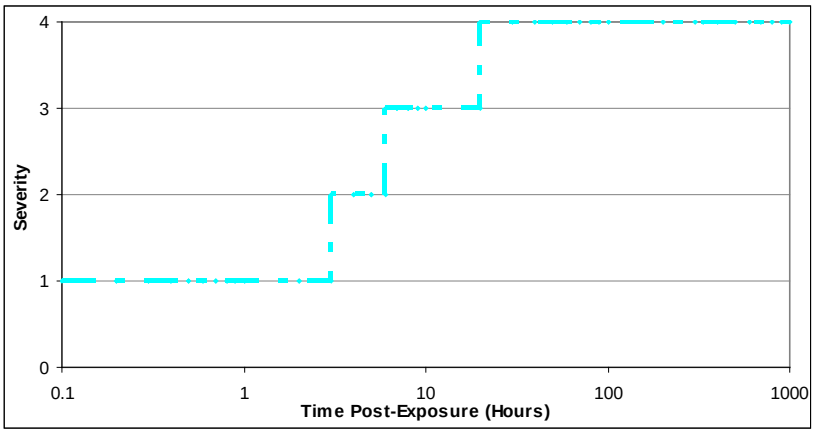

Figure 37. Cardiovascular Symptom Progression for Thermal Insult Range ≥ 30 %BSA

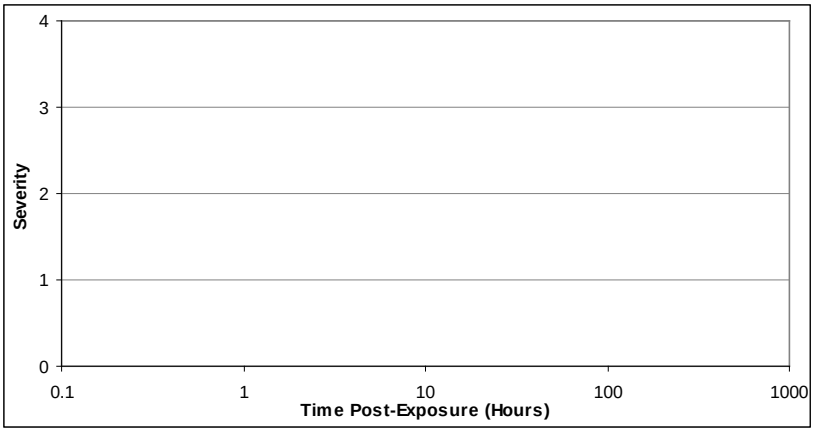

Figure 38. Immune Symptom Progression for Thermal Insult Range ≥ 30 %BSA*

*Immune symptoms are neglected in the ≥ 30 %BSA Thermal Insult Range.

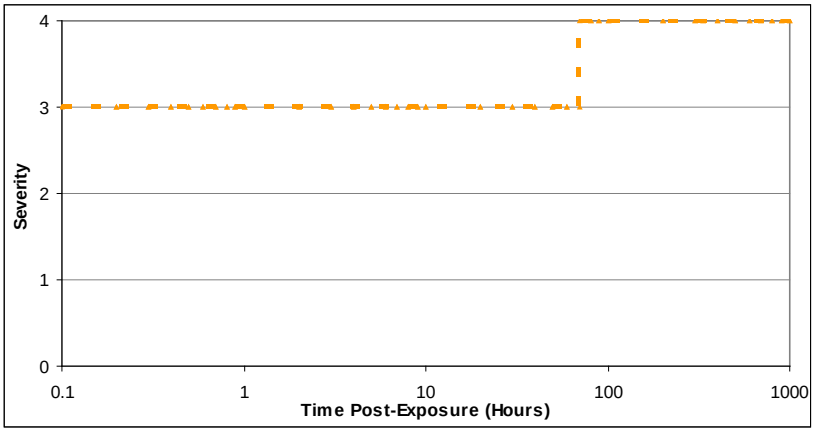

Figure 39. Skin Symptom Progression for Thermal Insult Range ≥ 30 %BSA

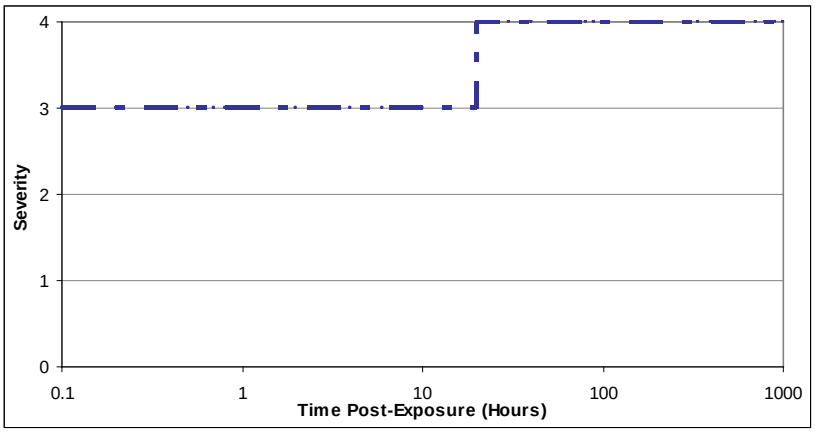

Figure 40. Injury Profile for
Thermal Insult Range ≥ 30 %BSA

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II. BRIEFINGS

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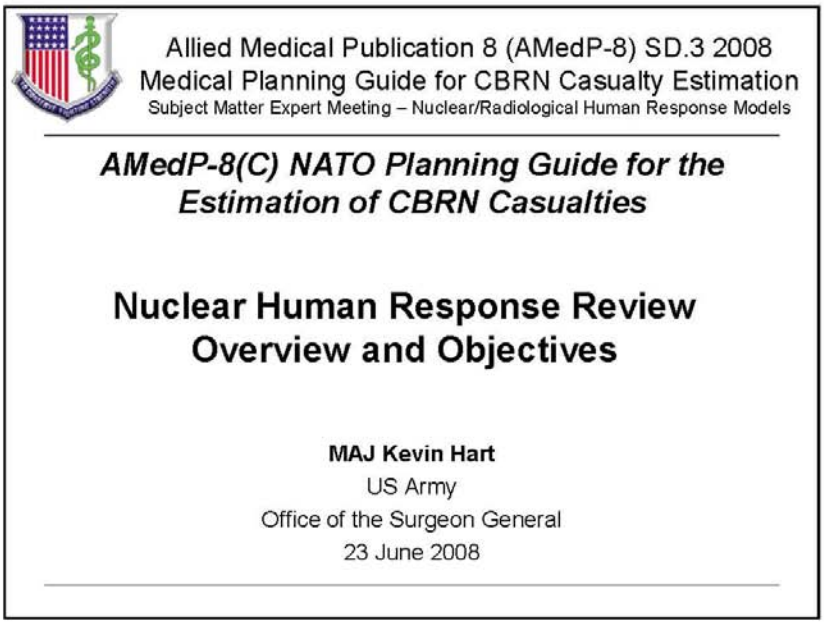
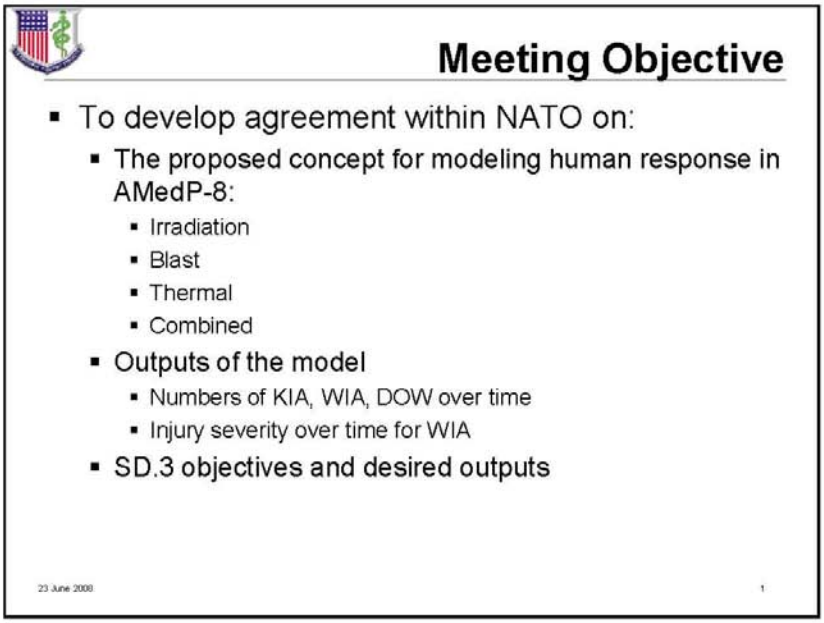
A. Nuclear Human Response Review Overview and Objectives – *Briefing*





AMedP-8(C) Purpose

- To provide a methodology for estimating casualties occurring as a consequence of chemical, biological, radiological or nuclear (CBRN) attacks against Allied targets, military or civilian, to support the NATO medical planning process. The methodology is designed to provide estimates of time dependence of the incidence of symptoms by type and severity, numbers of casualties, to include numbers of fatalities.

AMedP-8 (C) Background

- Part of series of Allied Medical Publications for NBC Planning and Response
  - AMedP-6(C), NATO Handbook on the Medical Aspects of NBC Defensive Operations
    - Treatment and Medical Management at the Physician – Patient level
  - AMedP-7(D), Concept of Operations for Medical Support in NBC Environments
    - Medical Management at the Unit/Operational Level
  - AMedP-8(B), Medical Planning Guide of NBC Battle Casualties
    - Casualty estimation at the Unit/Operational Level

Draft Development Process

- SD.1 – Outline of proposed document
- SD.2 – Description of methodology up to point of individual estimate of exposure
  - Algorithms and required parameters for components other than human response models
- SD.3 – Complete description of methodology, to include human response to CBRN agents and insults
  - Algorithms and required parameters for human response models
  - Casualty estimation methodology
- Connect to Casualty Estimation Tool
  - Provide input to NATO conventional casualty estimation tools
  - Provide additional capabilities to Nations, as necessary (unsupported)
- Technical Reference
  - Reference documentation available to NATO

Current Efforts

- STANAG 2476, Ed 2, Addendum to AMedP-8(B)
  - Ratified and promulgated 20 Dec 2007
- Development of Study 2553, Ed 1, AMedP-8(C) SD.3 - NATO Planning Guide For The Estimation Of CBRN Casualties (new version)
  - SD.2 distributed October 2007
  - SD.3 under development

AMedP-8(C) Study Timeline

- SD.3 (Describe algorithms and required parameters for human response models)
  - Custodial Meetings--review technical aspects of modeling human response with national Subject Matter Experts
    - 21-22 April 2008, Chemical agents (Munich, in conjunction with German Medical Chemical Conference)
    - 8-9 May 2008, Biological agents (San Lorenzo de El Escorial, in conjunction with 21st BioMedAC)
    - **23-26 June 2008, Nuclear effects & Radiological agents (Albuquerque, New Mexico)**
  - September 2008, "Virtual Custodial Meeting" for final pre-coordination review of CBRN casualty estimation (by correspondence)
  - November 2008, Publish SD.3 for review
  - February 2009, Custodial Meeting in conjunction with CBRNMedWG Meeting to adjudicate SD.3 comments and discuss input to NATO conventional casualty estimation tools (Brussels)

Agenda - Monday, June 23, 2008

0830 – 0900	Nuclear Objective & Meeting Overview – MAJ Kevin Hart, US Army
0900 – 1000	Invited Presentation – COL John Mercier, US Army
1000 – 1030	*Coffee Break*
1030 – 1200	General Nuclear Human Response Modeling Concepts – Dr. Carl Curling
1200 – 1300	*Lunch*
1300 – 1330	Nuclear Insult Ranges – Ms. Deena Disraelly
1330 – 1415	Illustrative Example – Nuclear – Dr. Robert Zirkle
1415 – 1500	Nuclear Human Response – Irradiation – Ms. Deena Disraelly
1500 – 1530	*Coffee Break*
1530 – 1700	Nuclear Human Response – Irradiation (continued) – Ms. Deena Disraelly
1800	*Group trip to Old Town, Albuquerque*

Agenda - Tuesday, June 24, 2008

0830 – 1030	Nuclear Human Response – Blast – Dr. Robert Zirkle
1030 – 1100	*Coffee Break*
1100 – 1200	Nuclear Human Response – Thermal – Dr. Carl Curling
1200 – 1300	*Lunch*
1300 – 1400	Nuclear Human Response – Thermal (continued) – Dr. Carl Curling
1400 – 1500	Nuclear Human Response – Combined – Ms. Deena Disraelly
1500 – 1530	*Coffee Break*
1530 – 1630	Nuclear Casualty Criteria – Dr. Carl Curling
1630 – 1700	Nuclear Review, Conclusions & Way Ahead – MAJ Kevin Hart, US Army
1800	*Group trip to Santa Fe*

Agenda - Wednesday, June 25, 2008

0800 – 1500	*Trinity Site Tour*
1800 – 2200	*Dinner at Sandia Peak*

Questions?

Contact

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CBRN Staff Officer
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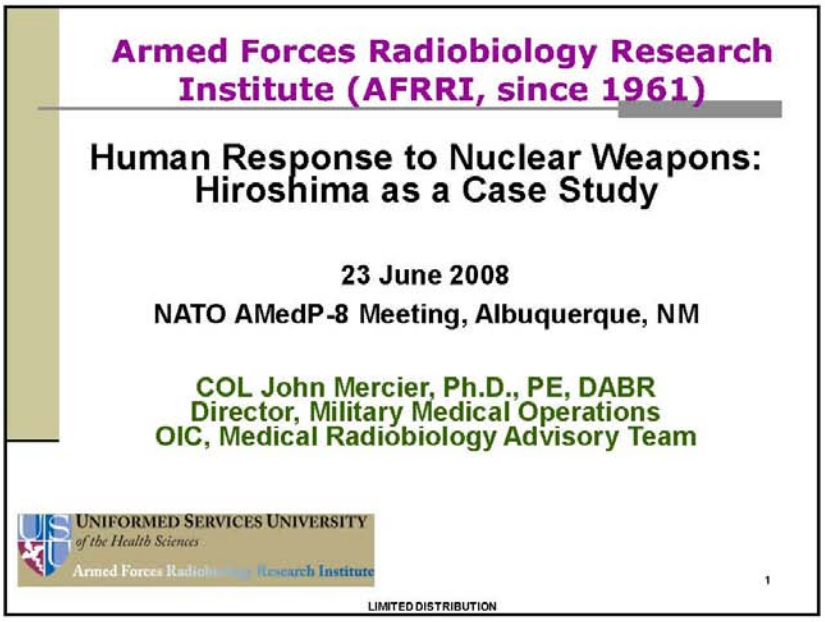
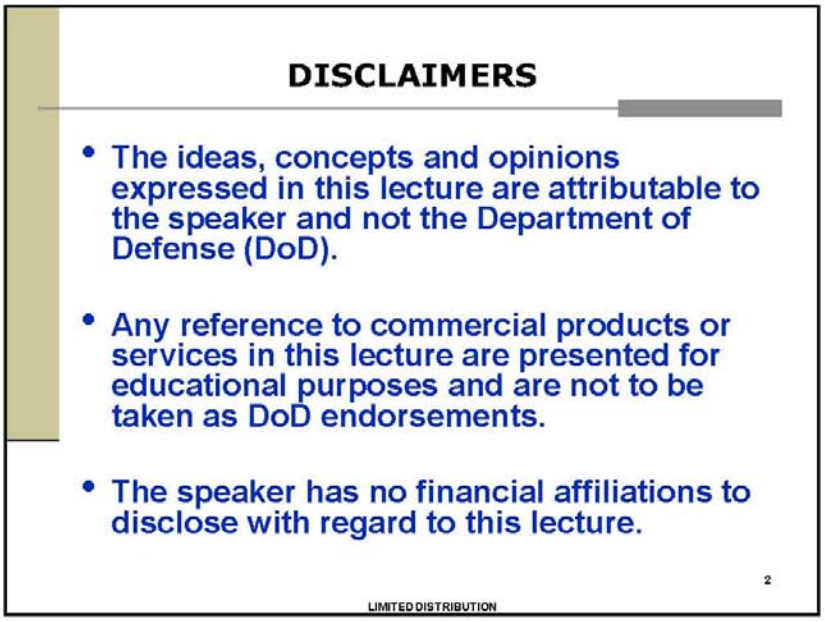
Falls Church, VA 22041-3258
Fax: (703) 681-4971

kevin.hart@us.army.mil
(703) 681-8185

B. Human Response to Nuclear Weapons: Hiroshima as a Case Study – *Briefing*





Objectives

- A look back at Hiroshima
- Human Response to NWE
  - Radiation
  - Blast
  - Thermal
- Probit method for nuclear casualty estimation

3

LIMITED DISTRIBUTION

Case Study: Hiroshima

- Little Boy (gun type wpn)
- 0815 a.m., 6 Aug 1945 (Enola Gay)
- 16 kT, 600m HOB (insignificant fallout)
- Clear weather, dense urban flat land
- ~10,000 people/sq km in city center
- 255,000 pop
  - 119,000 okay (47%)
  - 136,000 casualties (53%)
    - 64,000 deaths (25%) @ 4 mo
      - ½ to 1/3 in 1st day
      - Mostly those close in
    - 72,000 injured (28%)
      - Further out w/lower pop density

4

LIMITED DISTRIBUTION

Medical Statistics: Hiroshima

- Hospitals: 3/45 were functional (6.7%).
- Physicians: 59/298 were functional; only 28 without significant injury (9.4%).
- Nurses: 1654/1780 were casualties (92.9%).
- 10,000 injured patients went on their own or with assistance within 12 hours to the Red Cross Hospital (600 beds).
- In the biggest hospital, the Red Cross Hospital, only 6 out of 30 physicians were able to function. And only 10 out of 200 nurses were able to provide patient care.
- 70% of patients with combined injury.

5

LIMITED DISTRIBUTION

Hiroshima Casualties at the Red Cross Hospital (D +2, 1.6 km)

(August 8, 1945-Photo: Yotsugi Kawahara)

6

LIMITED DISTRIBUTION

Hiroshima Diary (Dr. Michihiko Hachiya) takes You Here During the Period 6Aug—30Sep, 1945

Hiroshima Teishin Hospital and Hiroshima Communications Bureau

Location: Moto-machi (now, Higashi-hakushima-cho)
Distance from hypocenter: approx. 1.4km

Photograph taken toward the west from the vicinity of the Hakushima streetcar stop. The two-story building in the front is the Teishin Hospital, while the four-story building in the rear is the Communications Bureau. Both had window frames and glass blown out by the blast, and at least half of the interior of each was destroyed by fire. Immediately after the bombing, the Communications Bureau building, too, was utilized to accommodate injured people; and even two months afterward, homeless people were living there.

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Case Study: Hiroshima

25 July 1945

11 August 1945

8

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Case Study: Hiroshima

9

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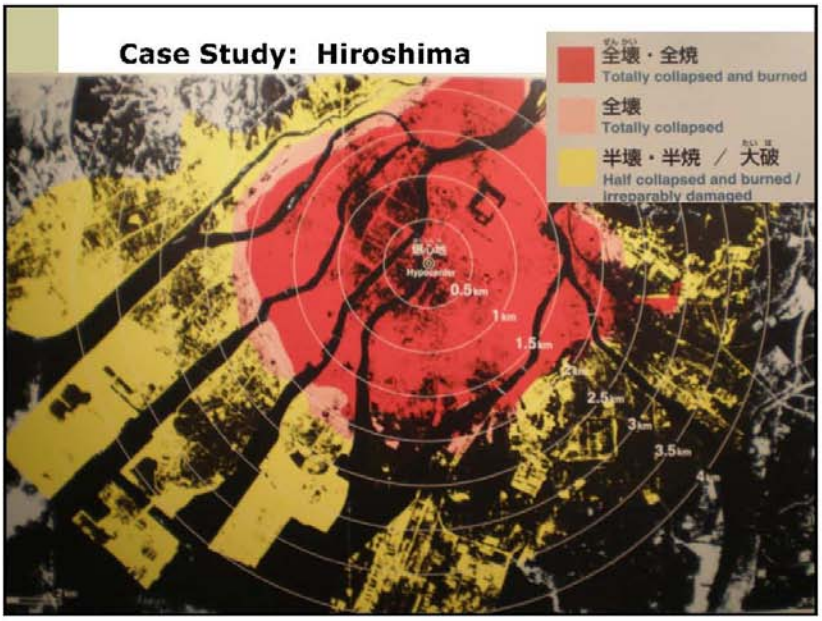
Case Study: Hiroshima



Case Study: Hiroshima

11

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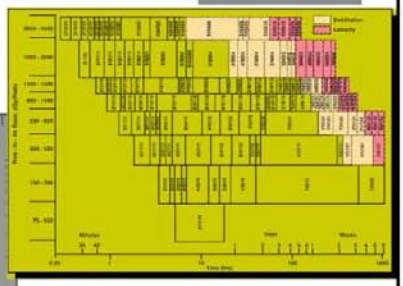
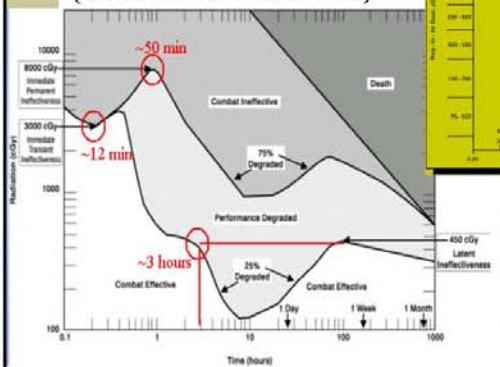
1970s and 1980s

Intermediate Dose Program ITI, IPI and LI Quantitative Biological Endpoints (Performance Decrement)





Combined Injury Program in 1980s followed the IDP

12

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Late 1990's

What about Collateral Damage and Consequence Management Modeling?

FI, SI, MI, NI, late effects …

13

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Effects to Understand, Quantify and Model

- **Radiation Effects:**
  - FI = Fatal Injury
  - SI = Serious Injury
  - MI = Minor/Moderate Injury
  - NI = Null/Negligible Injury
  - *Late effects, dose rate effects, Fallout (much to be done)*
- **Blast Effects**
  - Missiling
  - Direct overpressure
  - Translational Effects
- **Thermal Effects**
  - Flash Burns
  - Don't worry about flame burns
  - Ocular injury

Combined Injury

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LIMITED DISTRIBUTION

Quantitative Definitions

Use Chimzei & Shiroyama Nagasaki School Victims, Chernobyl Victims and Animal Data for Consensus Development and Publication of FI Probit Curves

15

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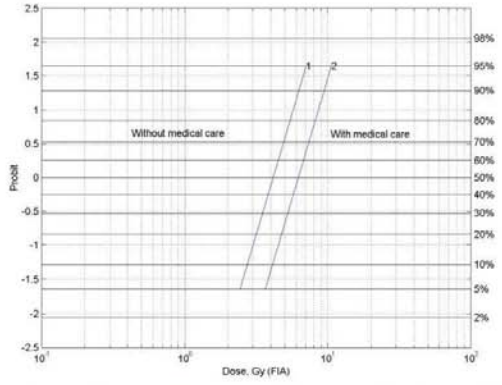
Fatal Injury Probits → Use Slope for SI and MI Probits



Anno, G., et. al, Dose Response Functions for Acute Radiation Lethality, Health Physics, 84(5), 2003, p. 565-575.

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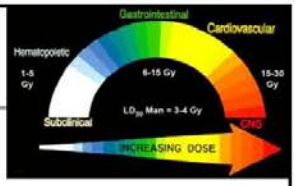
Radiation Injuries



- **Acute Radiation Syndrome (ARS)**
  - Classical Subsyndromes: H, GI, CV
  - Phases: Prodromal – Latent – Manifest Illness
  - New Paradigm: Grading of Multi-Organ Response
- **Skin injuries**
  - Erythema
  - Epilation
  - Purpura/Petechiae
- **Other effects**
  - Gingivitis
  - Conjunctivitis
  - Hypotension

Hiroshima ARS Victim (~D^{1}+20)

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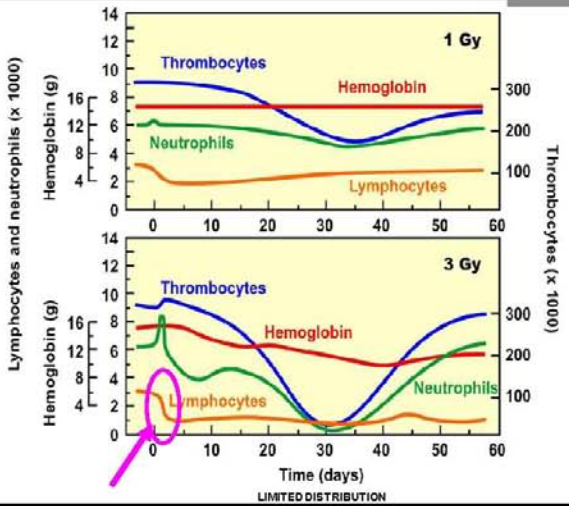
Radiation Injuries- Dose vs Severity and Time of Onset



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Quantitative Definitions

Use blood as biological endpoint to quantify SI and MI terms

19

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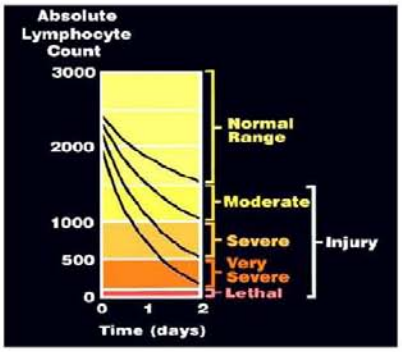
Quantitative Definitions: Lymphocyte Depletion



Ref. G. Andrews, Med Mgt of Acc Total-Body Irrad, in The Med Basis for Rad Acc Prep, K. Hubner and S. Fry (Eds), 1980. Also in NATO AMedP-6(C).

Figure shows >1500 Total Lymphcytes/µl as normal. Actually, 1300-2900 is normal range for Dewitt and Walter Reed Hospitals.

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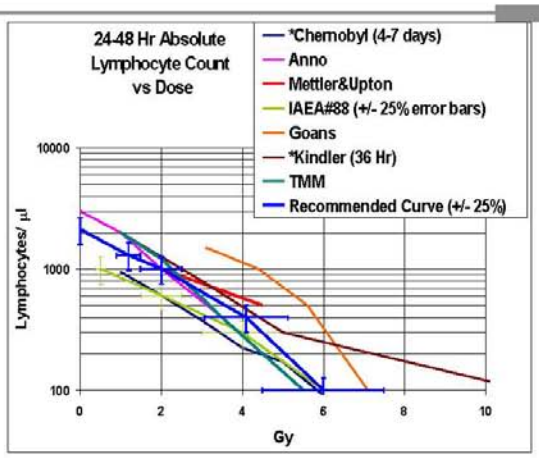
Quantitative Definitions: Lymphocyte Depletion



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Casualty Criteria Acute Radiation Syndrome (ARS) Guide

24 – 48 Hour Lymphocyte Count (x 1000/µl +/-25%)	Dose (FIA +/-25%)	Prognosis	Injury Interpretation
>1.3	<120 cGy	survival almost certain	NI
1 – 1.3	120-200 cGy	survival probable w/minimal or no care	MI
0.4 – 1.0	200-410 cGy	survival possible w/minimal or no care	SI
<0.4	>410 cGy	survival very improbable w/o care	FI

Anno, et al., and TMM put 400 cells/µl at LD50 which is the break point between SI and FI and which HR Panel put at 410 cGy FIA.

Consistent among several authors is break point between MI and SI at 1000-1200 cells/µl at a dose of 200 cGy. Above 200 cGy, NCRP #42 (1974) indicates most victims will require medical car

Break point between NI and MI appears at 1500 cells/µl by some authors. However, JRM used 13 cells/µl as the low end of the normal range indicated by calibrated blood counting systems at WRAMC. Several authors indicate a dose of 100 cGy at this break point. However, a dose of 120-130 cGy keeps the curve smooth at 1300 cells/µl .

The data point of 0 cGy at 2100 cells/µl is the midpoint of the normal range on calibrated blood counting systems at WRAMC

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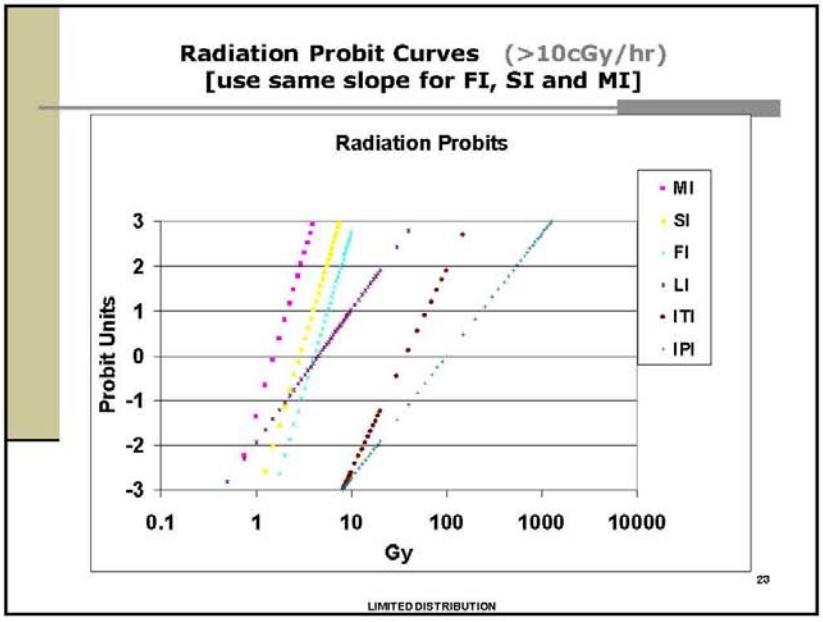
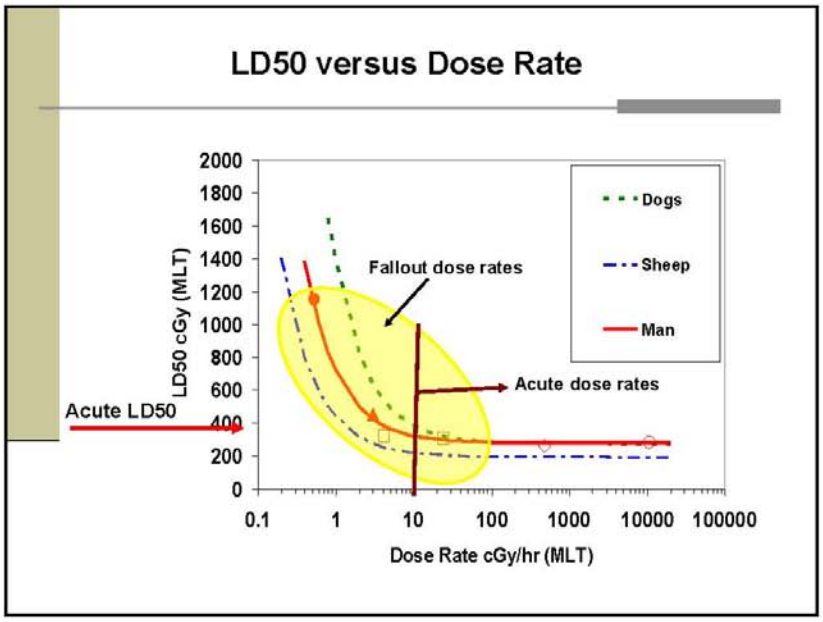

Radiation Probit Curves (>10cGy/hr)
[use same slope for FI, SI and MI]
Radiation Probits
Probit Units
3
2
1
0
-1
-2
-3
0.1
1
10
100
1000
10000
Gy
MI
SI
FI
LI
ITI
IPI
23
LIMITED DISTRIBUTION


LD50 versus Dose Rate
LD50 cGy (MLT)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Acute LD50
Fallout dose rates
Acute dose rates
Dogs
Sheep
Man
0.1
1
10
100
1000
10000
100000
Dose Rate cGy/hr (MLT)

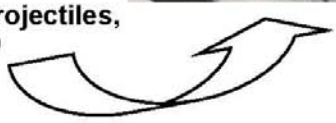
Blast Injuries

Direct overpressure

- Crushed building victims
- Air cavity injuries (e.g., ear, lung, gut)
  - ruptured viscera (organs)
  - alveolar hemorrhage
  - pulmonary edema

Dynamic pressure (nuclear winds)

- Translational effects
  - Decelerative tumbling (fractures, lacerations)
  - Impact with a solid surface (blunt trauma)
- Missiling effects (e.g., projectiles, flying shards of glass)



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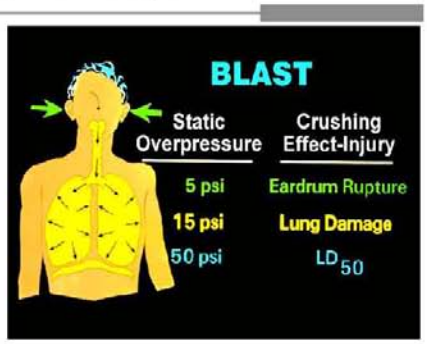
Photos: DOE, National

Direct Overpressure Injuries

Wood Frame: 5 psi peak overpressure



Direct overpressure data:				
Exposed Personnel for ALL Yields				
%incidence	MI	LI	SI	FI,ITI,IPI
5%	5.3	13.0	21.2	37.3
50%	15.8	18.0	29.0	47.6
99%	73.5	27.8	45.3	67.3

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Translational Injuries

Translational Injuries

Velocity * (m/sec)	Probability of blunt injuries and fractures	Probability of fatal injuries
2.6	> 1%	-
6.6	~ 50%	> 1%
17.0	99%	~ 50%
44.5	-	99%
* Velocities are based on solid impact with a non-yielding surface		

70 kg Human Body Displaced by Blast Wind Drag Forces

Weapon yield (kT)	Velocities * (m/sec)		
	2.6	6.6	17.0
1	0.38 km	0.27 km	0.19 km
10	1.0 km	0.75 km	0.53 km
100	2.5 km	1.9 km	1.4 km
1000	5.9 km	4.8 km	3.6 km
* Data account for ground friction and consider only prone personnel.			

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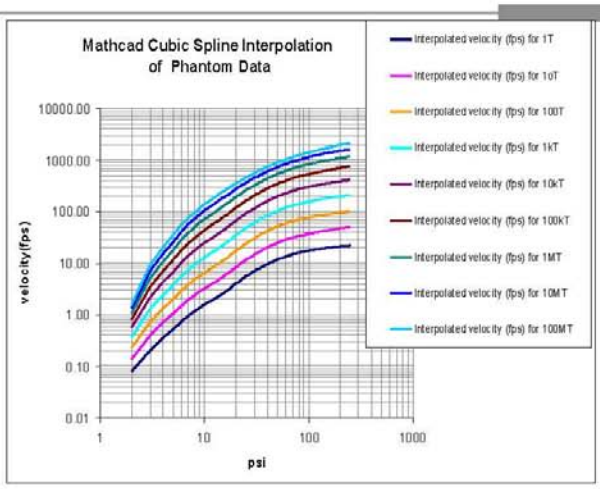
Translational Effects



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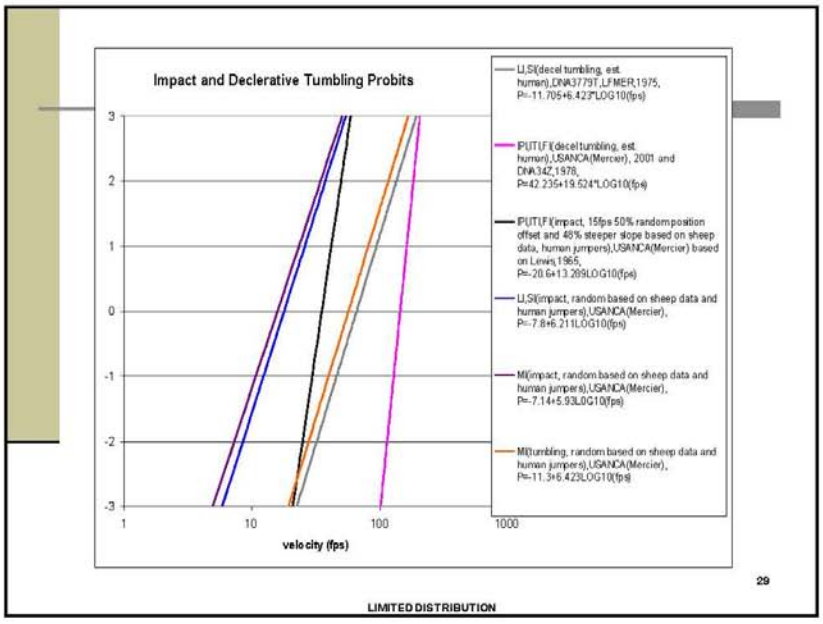
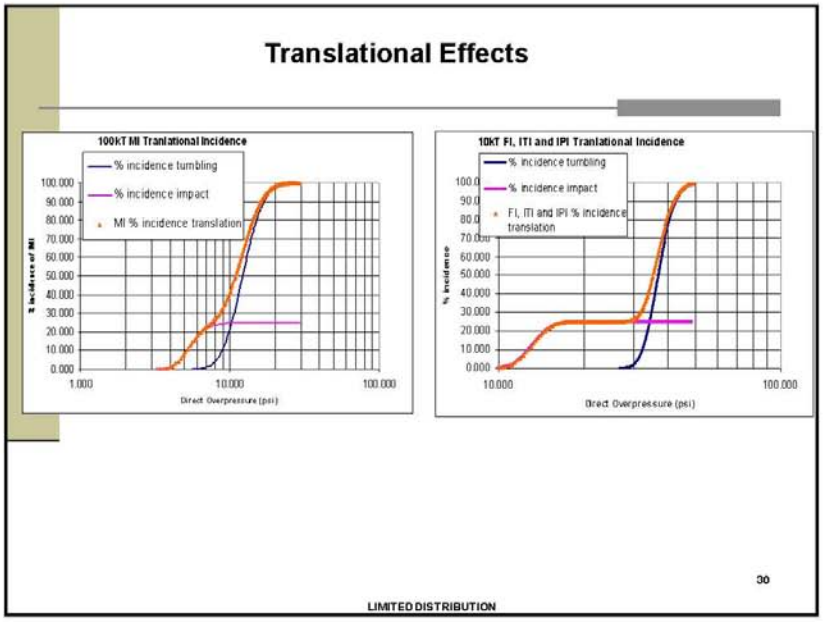

Impact and Declerative Tumbling Probits
velocity (fps)
LI,SI(decel tumbling, est. human),DNA3779T,LFMER,1975, P=-11.705+6.423*LOG10(fps)
IPI,ITI,FI(decel tumbling, est. human),USANCA(Mercier), 2001 and DNA 34Z,1978, P=42.235+19.524*LOG10(fps)
IPI,ITI,FI(impact, 15fps 50% random position offset and 48% steeper slope based on sheep data, human jumpers),USANCA(Mercier) based on Lewis,1965, P=-20.6+13.269LOG10(fps)
LI,SI(impact, random based on sheep data and human jumpers),USANCA(Mercier), P=-7.8+6.211LOG10(fps)
MI(impact, random based on sheep data and human jumpers),USANCA(Mercier), P=-7.14+5.93LOG10(fps)
MI(tumbling, random based on sheep data and human jumpers),USANCA(Mercier), P=-11.3+6.423LOG10(fps)
29
LIMITED DISTRIBUTION


Translational Effects
100kT MI Translational Incidence
% incidence tumbling
% incidence impact
MI % incidence translation
% Incidence of MI
Direct Overpressure (psi)
10kT FI, ITI and IPI Translational Incidence
% incidence tumbling
% incidence impact
FI, ITI and IPI % incidence translation
% Incidence
Direct Overpressure (psi)
30
LIMITED DISTRIBUTION

Thermal Injury

- Flame Burns (< 2% of 20-day survivors)
- Flash (Profile) Burns (> 50% patients)
- Flash blindness & retinal burns

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LIMITED DISTRIBUTION

Photos: DOE, National

Flash Burns

Negligible Injury:

<1% BSA 3deg

<5% BSA 2deg

<50% BSA 1deg

Moderate Injury:

1-5% BSA 3deg

5-15% BSA 2deg

50-100% BSA 1deg

Serious Injury:

5-25% BSA 3deg

15-50% BSA 2deg

Fatal Injury:

>25% BSA 3deg

>50% BSA 2deg

>40% BSA 2&3deg (any combo)

~2 km at
3-4 cal/cm2

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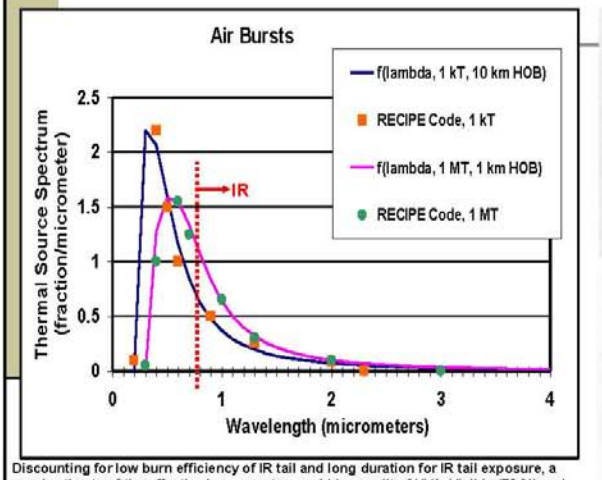
Thermal Pulse Spectra: UVA+Visible (60-70 %) and IR (30-40%)



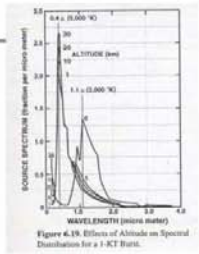


Figure 6.19. Effects of Altitude on Spectral Distribution for a 1-KT Burst.

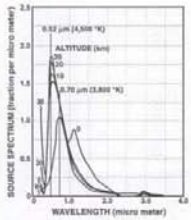


Figure 6.21. Effect of Altitude on Spectral Distribution for a 1-MT Burst.

Discounting for low burn efficiency of IR tail and long duration for IR tail exposure, a good estimate of the effective burn spectra would be a split of UVA+Visible (70 %) and IR (30%) to initial survivors for all yields. A 70/30 split is also suggested in EM-1.

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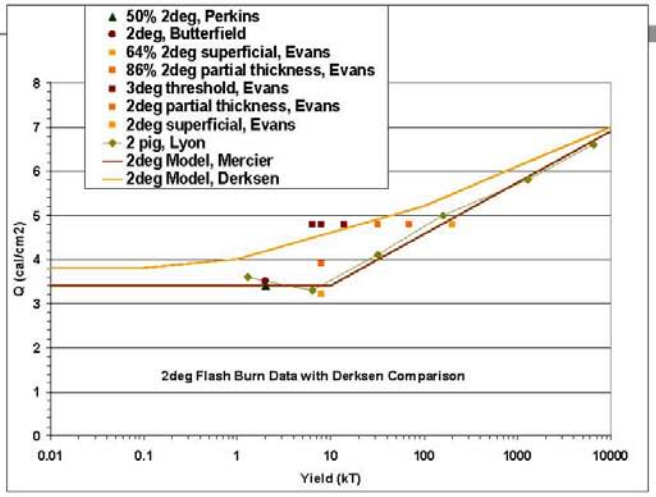
2nd Degree Burn Data/Models



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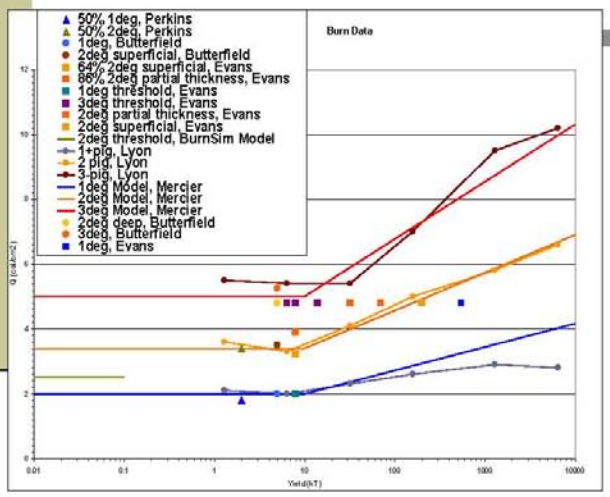
Burn Data/Models



Burn Ratios:

Low yield human and pig data @ Q2/Q1 = 1.8
Assume same ratio for high yields in model

Q3/Q2 ~ 1.3-1.7 for high yields in pig data and 1.3-1.5 in sparse human data at low yields. Assume ratio of 1.4 for model for all yields

Perkins data corrected by 0.86 via Evans, 1955.

From Drake (1978) and Heer (1952), error is about +/- 15 to 20 % in Q.

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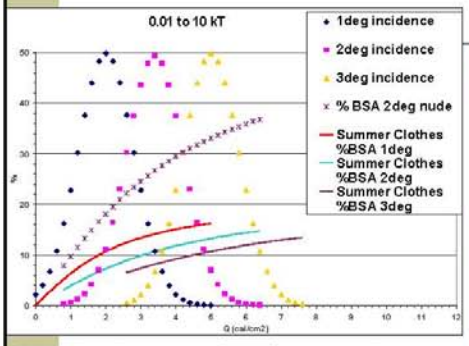
Casualty Model @ log normal probit method



Exposed -- in the open								
Yield (KT)-->			0.01 to 10					
Burn type-->	1deg		2deg		3deg			
Q (cal/cm2)	%incedence	%BSA burned	%incedence	%BSA burned	%incedence	%BSA burned	%BSA (2deg+3deg)	
0.2	4	3.4						
1	33	16	0.6	9.7			9.7	
2	60	27	11	18			18	
3	77	33	44	26	2.2	10	24.66666667	
3.4	80	35	50	27	7	20	26.14035088	
4	88	39	61	29	23	23	27.35714286	
5	89.7	40.5	83	33	50	27	30.66732394	
6			86.3	36	77	30	33.36451797	
7					97.5	33	33	

The BSA burned from a given fluence can be estimated from a set of geometry factors produced by Groce (1976). A reasonable fit to the Groce data is:

%BSA burned = 34*arctan(Qinc/Q50)

Where Qinc is the incident thermal dose to a cylinder and Q50 is the dose to yield 50% incidence of burns for a beam perpendicular to a flat surface area.

For summer, clothing is estimated to provide coverage to 80% of the body. So the burns from a given Qinc to the 20% bare skin are added to the burns from Qinc that penetrates the clothes.

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Flash Burn Casualty Criteria

Yield (KT)	0.01	0.1	1	10	100	1000	10000
Thermal Pulse 70% time (s)	0.03	0.08	0.23	0.61	1.64	4.44	12
ITI - not used for thermal criteria							
IPI - not used for thermal criteria							
			Exposed -- in the open				
		P(50% incidence) human flash burn criteria, Q (cal/cm2)					
MI - minor injury	2.5	2.5	2.5	2.5	3.5	4.5	5.5
SI - serious injury	3.4	3.4	3.4	3.4	4.6	5.7	6.9
FI - fatal injury	6	6	6	6	8	10	12
LI - Latent Ineffectiveness @ casualties	15	15	15	15	15	15	15
LI - Latent Ineffectiveness @ troop risk	9	9	9	9	9	9	9
		P(5% incidence) human flash burn criteria, Q (cal/cm2)					
MI - minor injury	1.4	1.4	1.4	1.4	2.8	3.2	4.15
SI - serious injury	1.725	1.725	1.725	1.725	2.3	3.96	5.1
FI - fatal injury	4.12	4.12	4.12	4.12	6	7.82	10
LI - Latent Ineffectiveness @ casualties	3.6	3.6	3.6	3.6	3.6	3.6	3.6
LI - Latent Ineffectiveness @ troop risk	2.2	2.2	2.2	2.2	2.2	2.2	2.2

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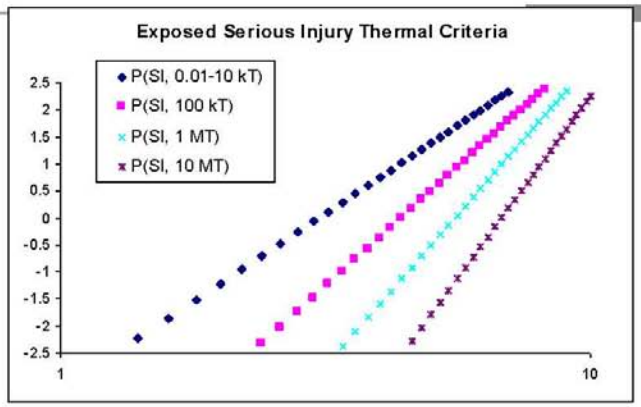
Casualty Model @ log normal probit method



Q (cal/sq cm)

38

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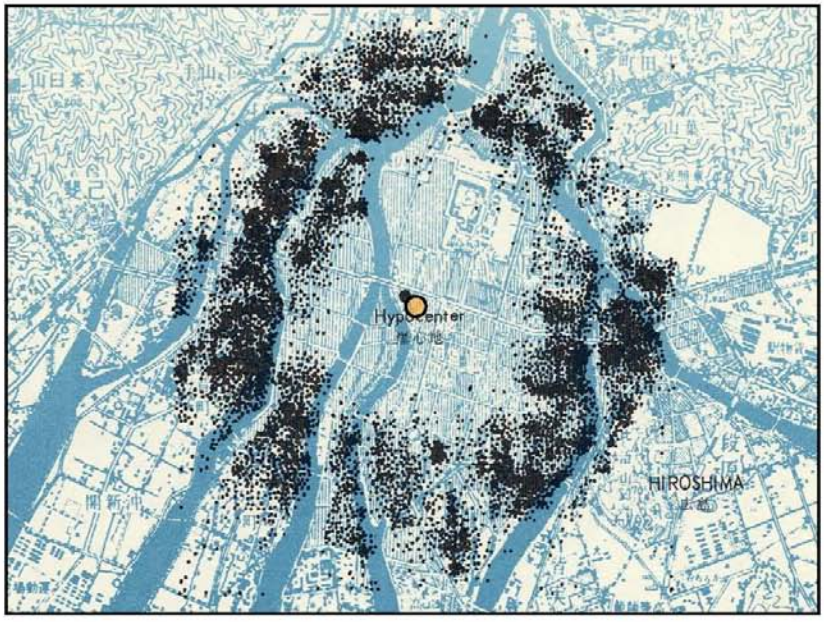
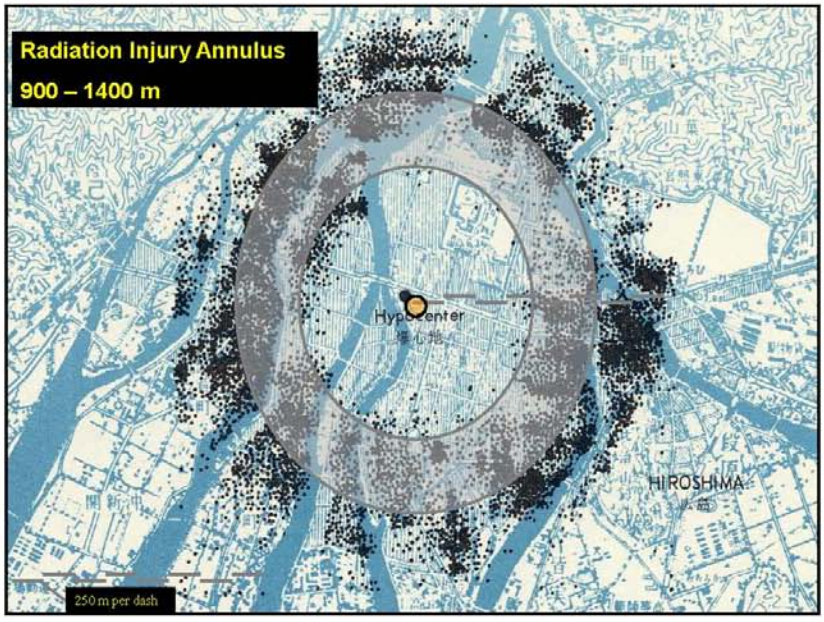
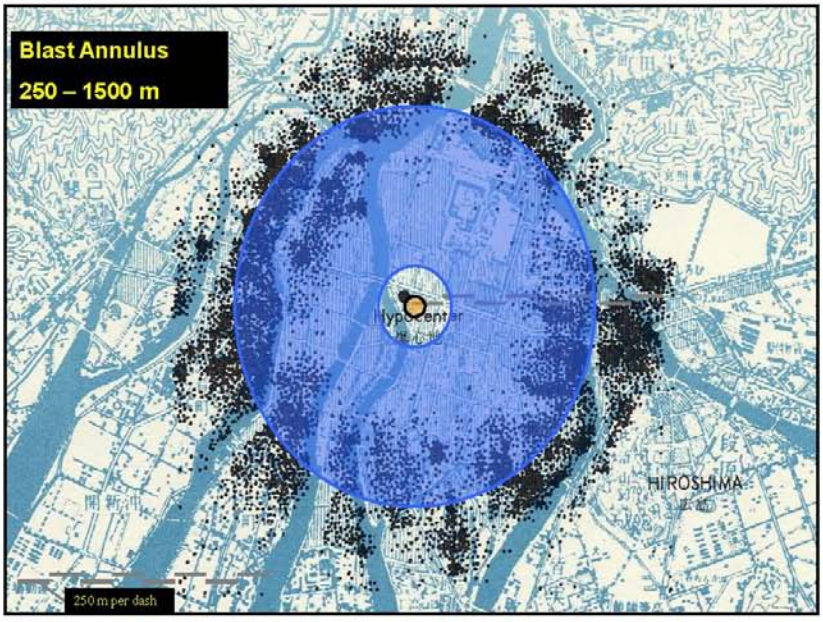
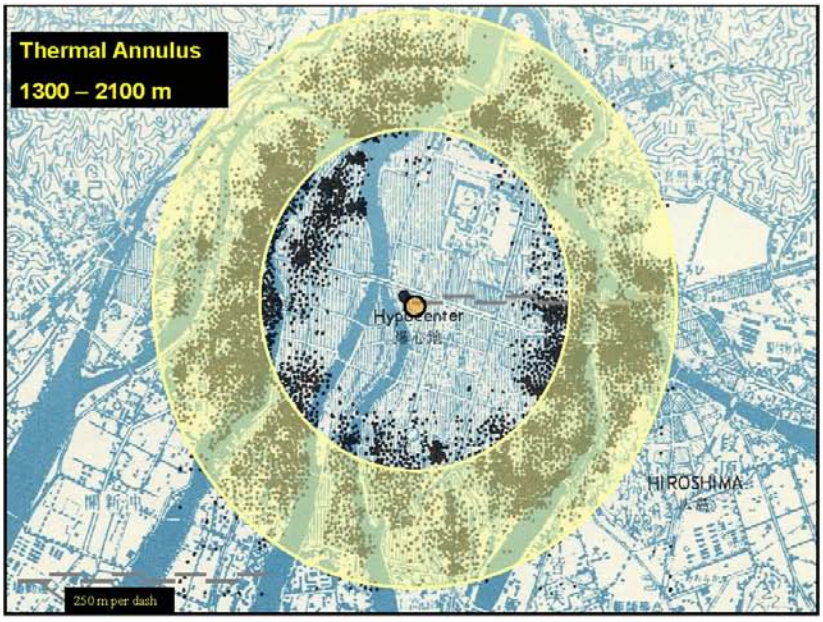
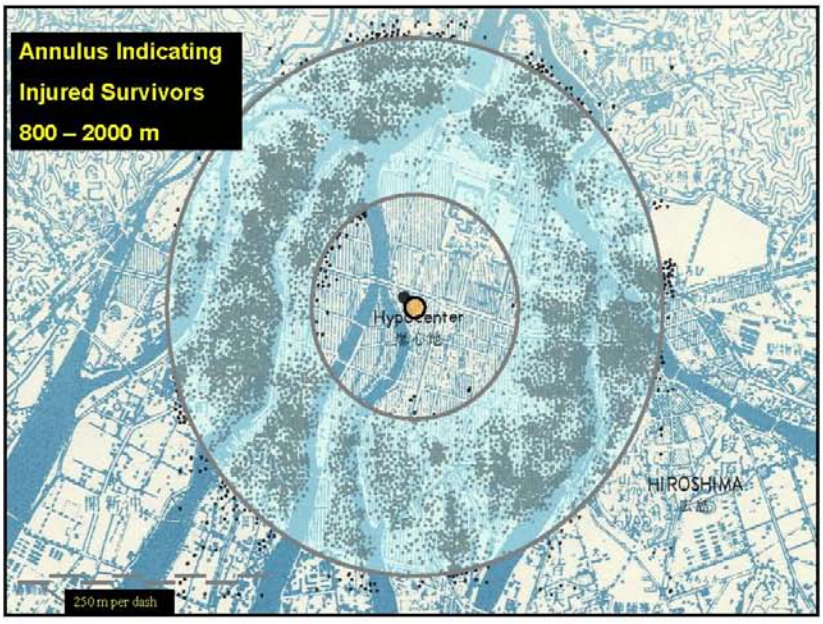
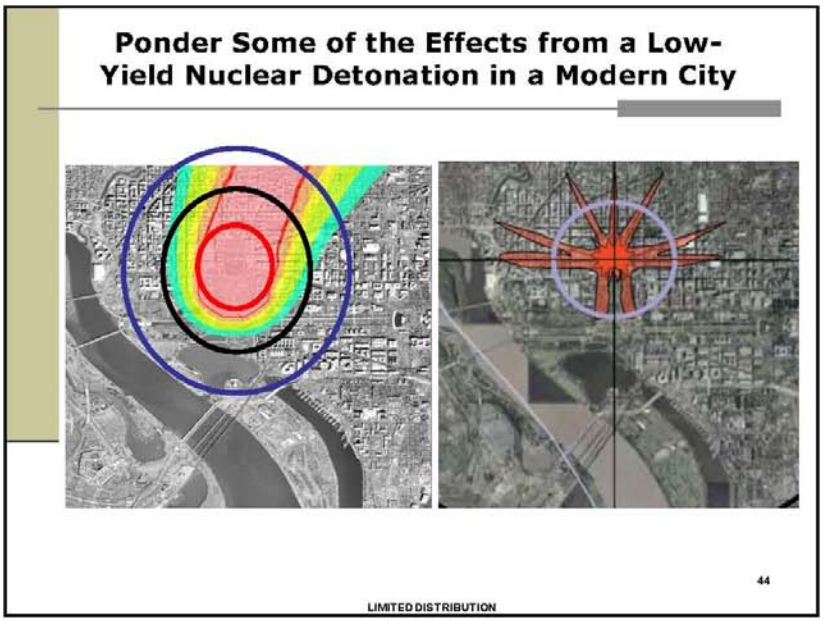

Hypocenter
HIROSHIMA


Radiation Injury Annulus
900 – 1400 m
Hypocenter
HIROSHIMA
250 m per dash


Blast Annulus
250 – 1500 m
Hypocenter
HIROSHIMA
250 m per dash


Thermal Annulus
1300 – 2100 m
Hypocenter
HIROSHIMA
250 m per dash


Annulus Indicating
Injured Survivors
800 – 2000 m
Hypocenter
HIROSHIMA
250 m per dash


Ponder Some of the Effects from a Low-Yield Nuclear Detonation in a Modern City
44
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Questions?

Hiroshima, H +3, 2 km

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Thank You for Listening

UNIFORMED SERVICES UNIVERSITY
of the Health Sciences

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301-272-0897 ← Cell: [redacted]
Fax: 301-295-0424
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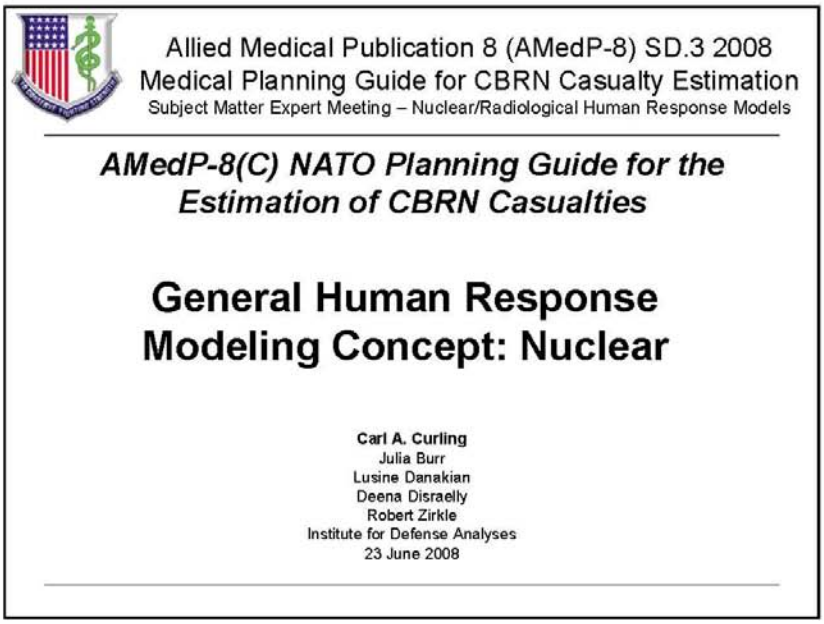
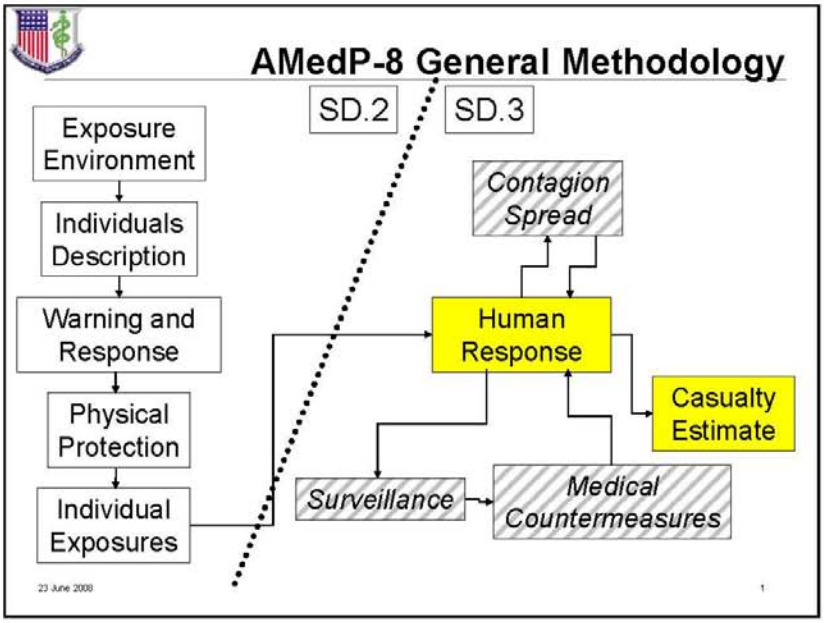
C. General Human Response Modeling Concept: Nuclear – *Briefing*





AMedP-8 Human Response Models

- The proposed Human Response Models:
  - Are described by injury profile maps which are based upon injury progression maps, or signs/symptoms severities over time
  - Allow for estimation of:
    - KIA as a function of specific levels of effect
    - WIA at the time at which signs/symptoms and/or injury reach a specified severity level or as a function of specific effect levels
    - DOW at some time after agent or effect exposure as a function of an agent/effect-related estimation or a specified severity level

AMedP-8 Human Response Models

- Estimates the status over time of personnel exposed to some Chemical, Biological, Radiological, or Nuclear agent or effect
- Estimates the number of people who:
  - May be expected to require medical treatment
  - Are anticipated KIA, WIA, and DOW due to the agent or effect exposure
- Does NOT anticipate the number of people who:
  - May seek medical assistance (battle stress cases)
  - May be injured or killed indirectly (i.e. as a result of car accidents, heart attacks, etc)

AMedP-8 Working Definitions

- **Human response model** (also known as a casualty estimation model)
  - Usually one component of a larger suite of models
  - Used to estimate status over time of personnel exposed to some event involving CBRN agents
  - The model does not anticipate the number of people who may seek medical assistance or the number who may be injured or killed indirectly (i.e. as a result of car accidents, heart attacks, etc)
- **Casualty**
  - "In relation to personnel, any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured or missing." (AAP-6)
- **Nuclear casualty**
  - "Any person who is lost to his organization by reason of having been declared dead, wounded or diseased as a result of exposure to nuclear flash, blast, heat or radiation." (AMedP-13)

Definitions from NATO documents: AMedP-8(C), AAP-6, and AMedP-13.

AMedP-8 Working Definitions (cont'd)

- **Injury**
  - *"Effects—including disease and wounds—resulting in the damage or deterioration of health"*
    - To encompass the full range of disease, wounds, and other trauma resulting from the nuclear R, B, & T insults, the term "injury" is introduced
    - Injuries may be caused by numerous external insults including chemical, biological, radiological, radiation, blast, and thermal hazards
    - NATO does not specifically define "injury"
      - The *NATO Glossary of NBC Terms and Definitions, English and French, Allied Administrative Publication-21* (AAP-21), defines "Medical Countermeasures (nuclear, chemical, and biological)" in terms of injuries—"those medical interventions designed to diminish the susceptibility of personnel to the lethal and damaging effects of chemical, biological and radiological hazards and to treat any injuries arising from exposure to such hazards."
      - Thus, this definition suggests that all damages to personnel health resulting from CBRN hazards may be classified as "injuries."

AMedP-8 Working Definitions

- **Killed in Action**
  - "A battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility." (AAP-6)
  - Based on conversations with NATO CBRN Medical Working Group participants, individuals will be assessed as KIA if their injury progression (or other method of calculation) suggests that they would express exposure effects resulting in imminent danger to life for at least 15 minutes before 30 minutes post-exposure
- **Wounded in Action**
  - "A battle casualty other than "killed in action" who has incurred an injury due to an external agent or cause. The term encompasses all kinds of wounds and other injuries incurred in action, whether there is a piercing of the body, as in a penetrating or perforated wound, or none, as in the contused wound; all fractures, burns, blast concussions, all effects of biological and chemical." (AAP-6)
- **Died of Wounds**
  - "A battle casualty who dies of wounds [or disease] or other injuries received in action, after having reached a medical treatment facility." (AAP-6)

Definitions from NATO documents: AMedP-8(C), AAP-6, and AMedP-13.

SD.3 Fundamental Concept

- An individual is considered a casualty at the time of first onset of illness/injury-specific signs/symptoms at a specified severity level

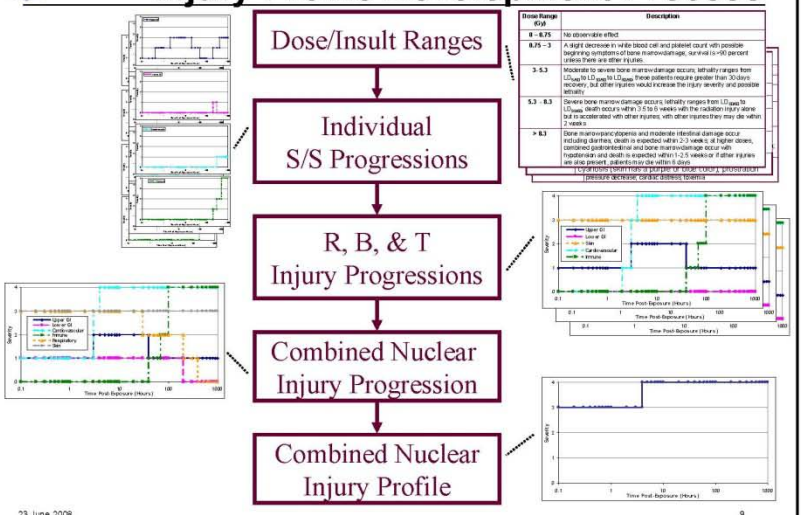
If (Severity at time t ≥ Effects Severity Level)
for any subset of symptoms at time t,
Then the individual is a casualty (WIA) at time t

- AMedP-8 specifies the symptoms over time that are used to determine whether an individual is declared dead, wounded, or injured and thereby considered to be a casualty
- The nature of symptoms and their times of onset depend on the agent

SD.3 Development Process

- Step 1: Identification of CBRN agents and effects and applicable routes of exposure
- Step 2: Identification of appropriate systems, signs & symptoms for each agent and effect
- **Step 3: With the assistance of SMEs, achieve consensus on the signs and symptoms maps for each agent and effect**
- Step 4: Determine the applicable estimation values:
  - Effects levels resulting in KIA
  - Signs and symptoms severity associated with WIA
  - Dose/Effects-related algorithms and/or signs and symptoms severities likely to result in DOW

Injury Profile Development Process



Human Response Methodology Inputs

- Nuclear environments:
  - Radiation [Gy]
  - Blast [kPa]
  - Thermal [% Body Surface Area Burned]
    - Converted from J/cm^2
    - %BSA is the percent area of skin with 2nd degree burns and may include 3rd degree burns

Users can calculate nuclear environments using their choice of methods, programs, or tools

Signs / Symptoms Systems

	Irradiation	Blast	Thermal
Cardiovascular	X	X	X
Immune	X		X
Lower Gastrointestinal	X	X	
Respiratory		X	
Skin (Thermal)			X
Upper Gastrointestinal	X	X	X

Severity Definitions

- No Observable Effect ≈ Severity = 0
- Mild ≈ Severity = 1
- Moderate ≈ Severity = 2
- Severe ≈ Severity = 3
- Very Severe ≈ Severity = 4

Severity Definitions

	Degrees	Description
0	N.O.E.	No observable effect
1	Mild	Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms
2	Moderate	Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission
3	Severe	Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms
4	Very Severe	Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms

Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related signs and symptoms
  - Dose-related signs and symptoms apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- Human response is modeled as primary response to prompt, instantaneous nuclear insults
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted
  - Human response for the entire exposed population begins simultaneously immediately following the nuclear detonation

Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization

Additional insult specific assumptions will be discussed by insult

Model Limitations

- The model cannot address several types of casualties
  - The model does not address battle stress cases
  - Secondary, higher order, and indirect casualties and secondary infections/diseases are not modeled
- Medical countermeasures and medical treatments are not addressed – all injury progressions assume no medical intervention
- The model does not attempt to account for recovery

Model Strengths & Weaknesses

- Model represents both the personnel status and injury progression and flow over time
  - Planners can select and collate data as desired
- Model allows the user to determine the severity level at which effects are expected to cause WIA
- Model is deterministic and based on the median individual
  - It does not allow for variations of dose-response as might be expected in an actual population
- Much of the model is based on data which is ten or more years old
  - Additional review with SMEs may be required to determine if more recent research would change proposed injury progressions

Questions?

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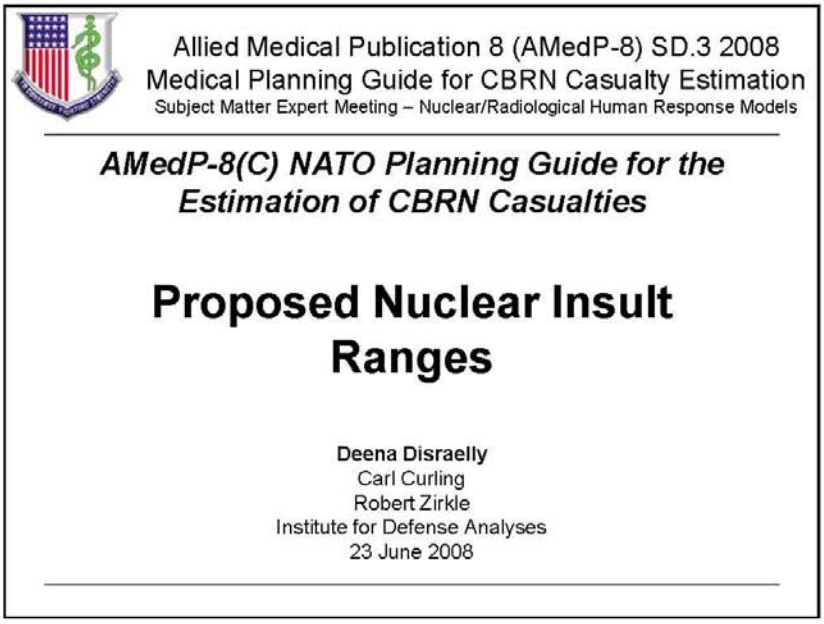
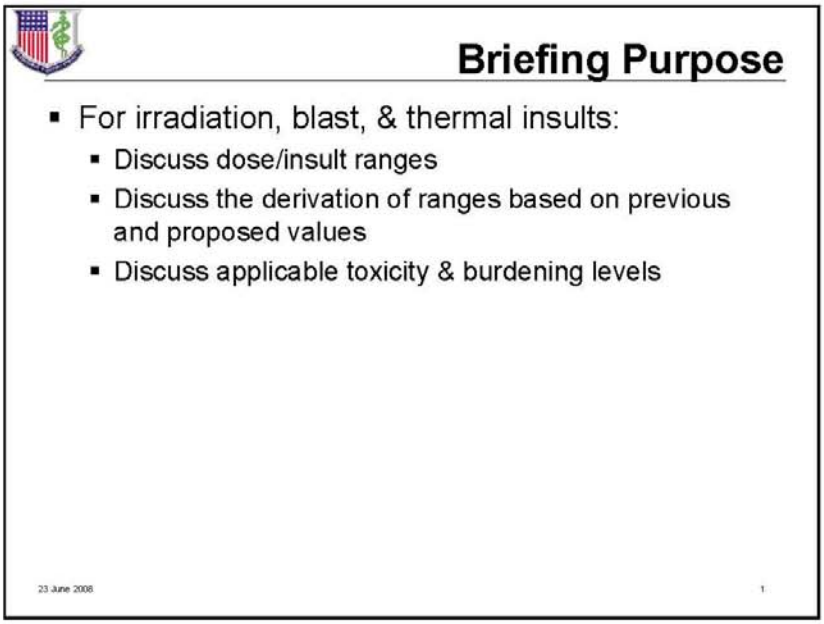
D. Proposed Nuclear Insult Ranges – *Briefing*





IRRADIATION DOSE RANGES

Radiation Dose Range

Dose Range (Gy)	Description
0 – 0.75	No observable effect
0.75 – 3	A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is >90 percent unless there are other injuries
3 – 5.3	Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible lethality
5.3 – 8.3	Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries they may die within 2 weeks
> 8.3	Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2-3 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1-2.5 weeks or if other injuries are also present, patients may die within 6 days

Derived from NATO. *AMedP-8. Op. cit.* p. 3-9; and NATO. *STANAG 2083*

Radiation Dose Range

- Sources:
  - NATO. *STANAG 2083, Commander's Guide on Nuclear Radiation Exposure of Groups During War*, 2003.
  - NATO. *STANAG 2475, Medical Planning Guide of NBC Battle Casualties: Nuclear, AMedP-8(A),* 2002.

Radiation Toxicity Values

- Reference Values
  - Mortality Threshold
    - 1.5 Gy MTD
    - 2.1 Gy FIA
  - $LD_{50/60}$ (minimal care)
    - 3.2–3.6 Gy MTD
    - 4.6–5.1 Gy FIA
  - $LD_{50/60}$ (supportive care)
    - 4.8–5.4 Gy MTD
    - 6.8–7.7 Gy FIA

Conversion factor of 1.42 Free in Air/Midline Tissue Dose

Sources: IAEA. "Acute Radiation Syndrome: Clinical Picture, Diagnosis, and Treatment"; IAEA. "Dose-Effect Curves; Deterministic and Stochastic Effects of Radiation"

Radiation Toxicity Values

Radiation Time-to-Death Values

FIA	Time		Hours	Source
220	60	Days	1440	(Solomon and Marston, 1986)
400	60	Days	1440	(NCRP 138, 2001)
400	60	Days	1440	(NCRP 138, 2001)
430	60	Days	1440	(TMM, 1989)
530	60	Days	1440	(Conklin and Walker, 1987)
530	60	Days	1440	(Pizzarello and Witcofski, 1982)
450	5	Weeks	840	(Conklin and Walker, 1987)
375	30	Days	720	(Mettler and Mosely, 1985)
700	30	Days	720	(Cember, 1987)
985	17.5	Days	420	(Conklin and Walker, 1987)
1326	17.5	Days	420	(Conklin and Walker, 1987)
1326	15.5	Days	372	(Conklin and Walker, 1987)
1364	11	Days	264	(Mettler and Mosely, 1985)
2273	10.5	Weeks	252	(Conklin and Walker, 1987)
2273	8.5	Days	204	(Conklin and Walker, 1987)
2273	7	Days	168	(Mettler and Mosely, 1985)
3030	3.5	Days	84	(Mettler and Mosely, 1985)
3788	3.5	Days	84	(Conklin and Walker, 1987)

BLAST INSULT RANGES

Blast Insult Range

- Burdening Level (BD)
  - Insult level resulting in some specified type of insult-induced injury (i.e. tympanic rupture) in a percentage of the population
    - e.g. BD_{50} Lung Injury is the burdening level expressed in kPa at which 50% of the population are expected to experience injury to the lungs
    - Equivalent to the values represented as an median effective dose (ED_{50}) or median lethal dose (LD_{50}) for radiation
  - Indicate the associated pressure which would result in injuries that require aid from another individual, especially a health-care professional
  - Originally introduced as a method of estimating the burden that would be placed on the health care system and survivors

23 June 2008

Source: Drake, et. al. *An Interim Report on Collateral Damage*, 1979.

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Blast Insult Range

Exp. Range (kPa)	Description
< 50	No observable effect
50 – 140	50% eardrum rupture; threshold lung damage; threshold gastrointestinal damage
140 – 240	50% burdening level (BD_{50}) lung damage; 90% burdening level (BD_{90}) tympanic membrane rupture
240 – 290	90% burdening level (BD_{90}) lung damage; 10% fatalities (LD_{10})
> 290	50% fatalities (LD_{50})

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Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

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Blast Insult Range

Exp. Range (kPa)	Description
0	Begin Range 1
~ 48	No observable GI tract injury (Drake, 1979; Richmond, 1991; Levin, 1993)
50	End Range 1 – Begin Range 2
~ 50 ~ 70 100-140	BD_{01} Tympanic membrane casualty (Drake, 1979) No observable lung injury (Drake, 1979; Richmond, 1991; Levin, 1993) BD_{50} Tympanic membrane casualty (Drake, 1979)
140	End Range 2 – Begin Range 3
~ 160 ~ 200	Moderate GI injury – small area submucosal contusions (Richmond, 1991; Levin, 1993) Moderate lung injury – <30% area confluent (Richmond, 1991; Levin, 1993)
240	End Range 3 – Begin Range 4
~ 260 ~ 260	Very severe GI injury – disruption of mucosal layer with perforation, hemorrhage or rupture (Richmond, 1991; Levin, 1993) BD_{50} Lethality – perpendicular to blast wave (Bowen)
290	End Range 4 – Begin Range 5
~ 290 ~ 290 ~ 440	BD_{50} Lethality (PRCC, 1991) Very severe lung injury – >60% lung area and/or entire lobes confluent (Richmond, 1991; Levin, 1993) BD_{50} Lethality – prone and parallel to blast wave (Bowen)

23 June 2008

Sources: Levin. *The Effect of Combined Injuries from a Nuclear Detonation on Soldier Performance*, June 1993; Richmond. *Primary Blast Injuries in the Open and in Foxholes Resulting from Nuclear Type Detonations*, 1991; Drake, et. al. *An Interim Report on Collateral Damage*, 1979; PRCC, 1991; and, Bowen as cited by SMEs, 2008.

THERMAL INSULT RANGE

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Thermal Insult Range

- In AMedP-8(B), thermal insult range was determined as a function of thermal fluence
  - Result was range bands with similar insult due to differing uniform types
- Propose to shift thermal insult range to be injury severity dependent
  - Based on %BSA calculated as a function of thermal fluence and uniform type

Thermal Insult Range

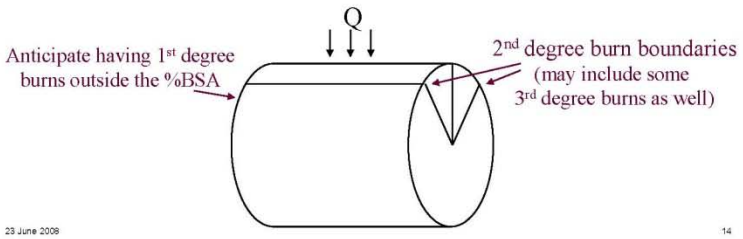
Thermal Insult Range (% BSA)	Description*
< 1%	No observable effect**
1 – 10%	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
11 – 20%	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
21 – 30%	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain
31 – 40%	10% fatalities; increased upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; decreased blood pressure (possibility of shock); initial increase in pain followed by a decrease in pain; compromise of the immune system
≥ 41%	50% fatalities; upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia

* Estimation of burn lethality is approximate
** <1%BSA may include a larger area of 1st degree burns

Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

% Body Surface Area Burned

- To calculate %BSA, a cylindrical model of the body was selected.
  - Burn depth and area was expected to increase as thermal fluence increased
  - Threshold values for %BSA with varying uniforms types was derived by Harry Diamond Labs



% Body Surface Area Burned

- Calculating %BSA:

$$\%BSA = \left[\frac{\text{arccosine}\left(\frac{Q_t}{Q}\right)}{\pi} \right] \cdot 100\%$$

- Where:
  - %BSA = % body surface area burned
  - Q_t = threshold value for a second degree burn
  - Q = thermal fluence to which the cylinder (body) is exposed

Levin. *The Effect of Combined Injuries from a Nuclear Detonation on Soldier Performance*. Espanola, NM: Technico Southwest, Inc, June 1993. p. 24.

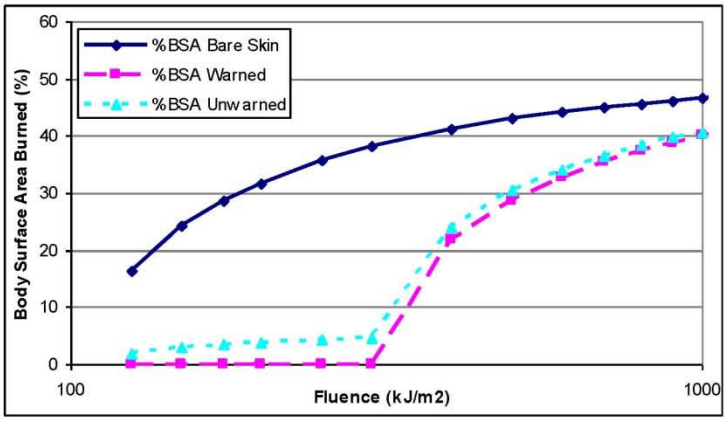
% Body Surface Area Burned

- Threshold burn values resulting in 2nd degree burns are uniform dependent
  - Bare skin 109 kJ/m^2
  - BDU + T-shirt (no bare skin) 310 kJ/m^2
- AMedP-8(A) utilizes two postures and the associated uniform types
  - Unwarned BDU + T-shirt (12% bare skin)
  - Warned BDU + T-shirt (no bare skin)

% Body Surface Area Burned

Fluence (kJ/m^2)	% BSA Bare Skin	% BSA Unwarned	% BSA Warned
125.0	16.4	2.0	0.0
150.0	24.2	2.9	0.0
175.0	28.6	3.4	0.0
200.0	31.7	3.8	0.0
300.0	38.2	4.6	0.0
400.0	41.2	24.1	21.8
500.0	43.0	30.4	28.7
1000.0	46.5	40.8	40.0
1500.0	47.7	43.9	43.4
2000.0	48.3	45.4	45.0
2500.0	48.6	46.4	46.0
3000.0	48.8	47.0	46.7

% Body Surface Area Burned



23 June 2009

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Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

Questions?

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703-578-2814	703-845-6685	703-845-2038

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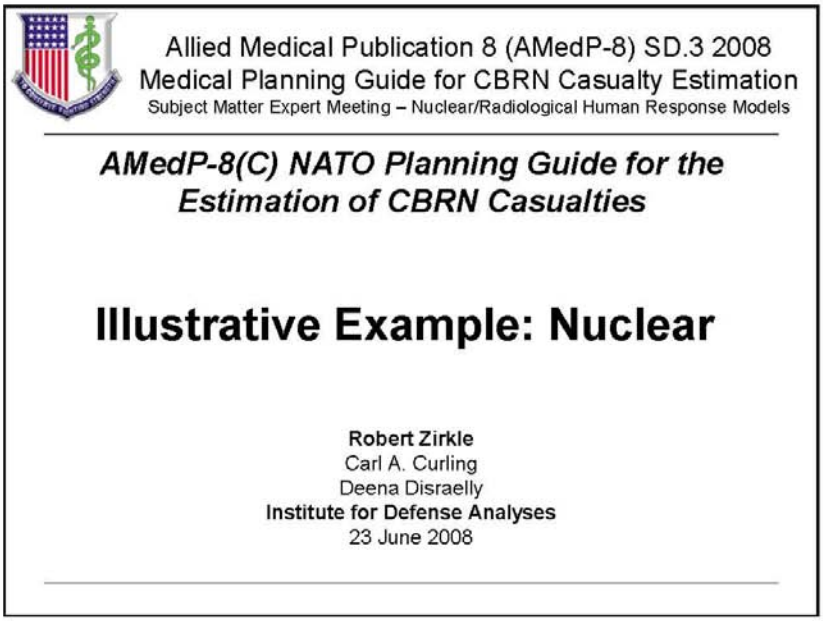
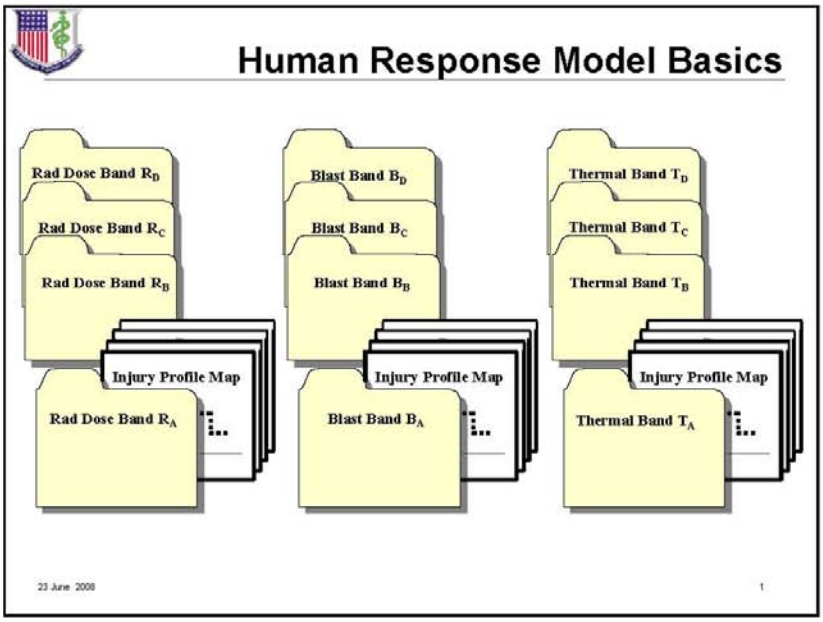
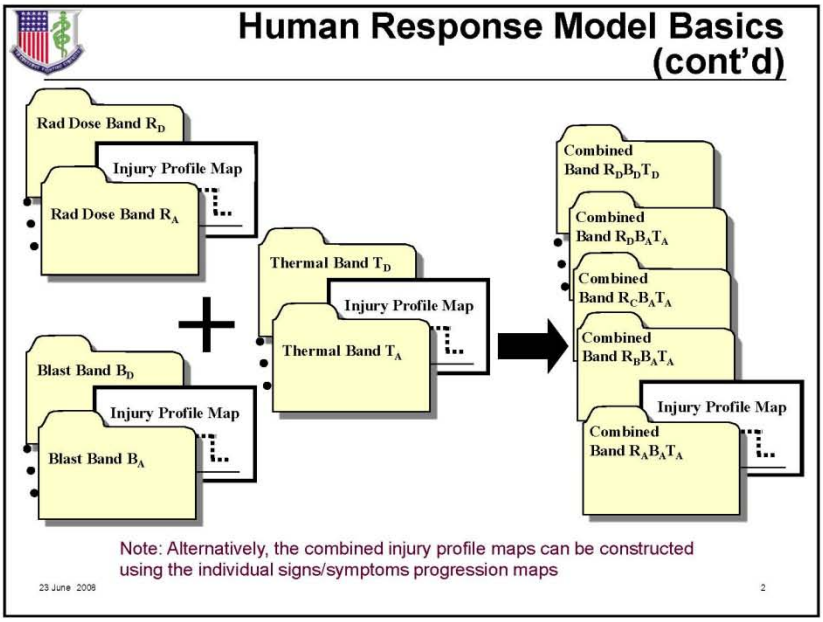
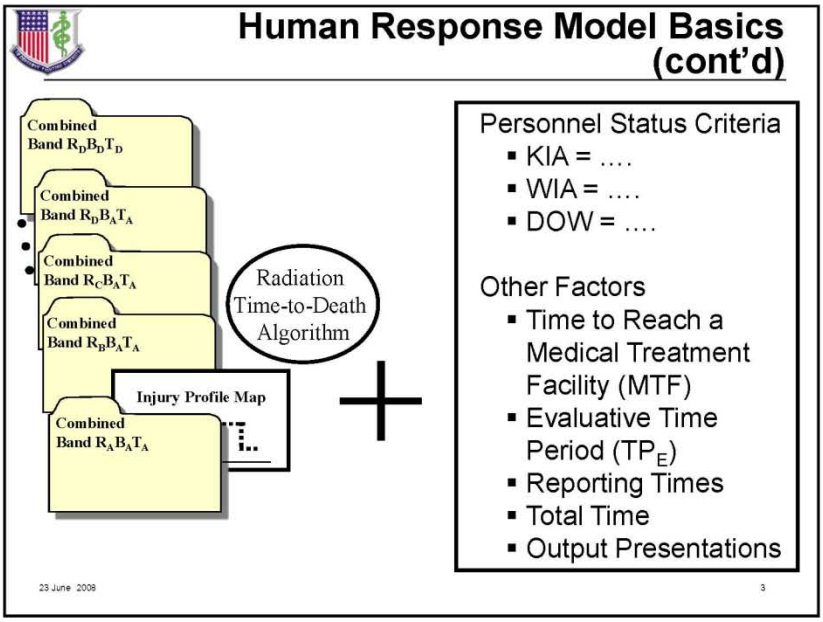
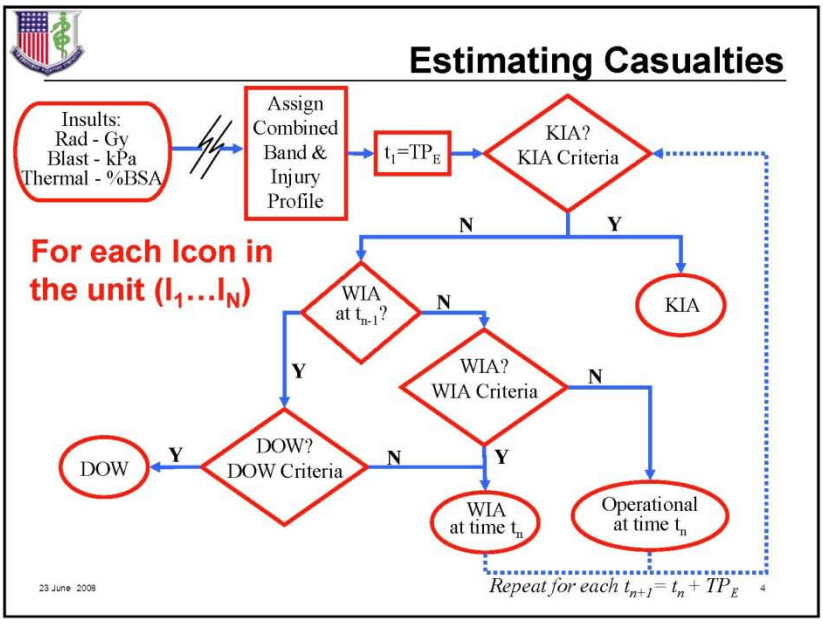
E. Illustrative Example: Nuclear – *Briefing*

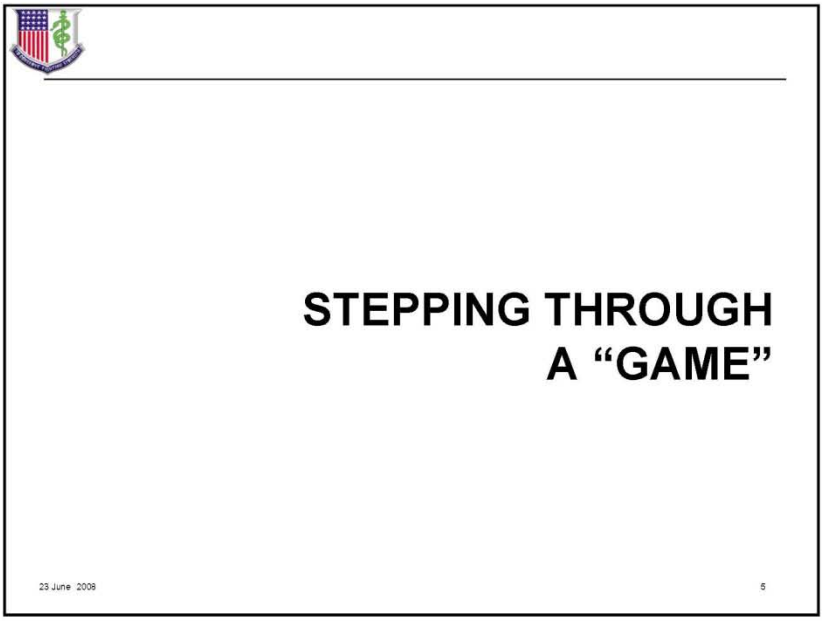





Human Response Model Basics (cont'd)
Rad Dose Band R_D
Injury Profile Map
Rad Dose Band R_A
Thermal Band T_D
Injury Profile Map
Thermal Band T_A
Blast Band B_D
Injury Profile Map
Blast Band B_A
Combined Band $R_DB_DT_D$
Combined Band $R_DB_AT_A$
Combined Band $R_CB_AT_A$
Combined Band $R_BB_AT_A$
Injury Profile Map
Combined Band $R_AB_AT_A$
Note: Alternatively, the combined injury profile maps can be constructed using the individual signs/symptoms progression maps
23 June 2008
2


Human Response Model Basics (cont'd)
Combined Band $R_DB_DT_D$
Combined Band $R_DB_AT_A$
Combined Band $R_CB_AT_A$
Combined Band $R_BB_AT_A$
Injury Profile Map
Combined Band $R_AB_AT_A$
Radiation Time-to-Death Algorithm
Personnel Status Criteria
KIA = ….
WIA = ….
DOW = ….
Other Factors
Time to Reach a Medical Treatment Facility (MTF)
Evaluative Time Period (TP_E)
Reporting Times
Total Time
Output Presentations
23 June 2008
3

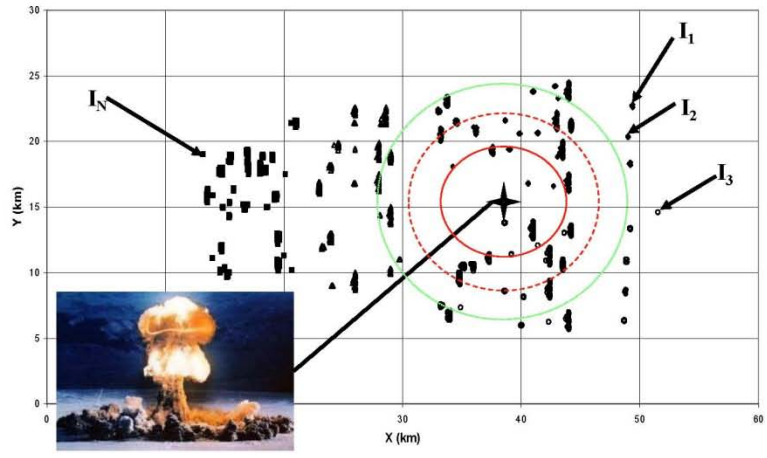

Estimating Casualties
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign Combined Band & Injury Profile
t_1=TP_E
KIA?
KIA Criteria
N
Y
For each Icon in the unit (I_1…I_N)
WIA at t_{n-1}?
N
KIA
Y
WIA?
WIA Criteria
N
DOW
Y
DOW?
DOW Criteria
N
Y
WIA at time t_n
Operational at time t_n
23 June 2008
Repeat for each t_{n+1}= t_n + TP_E
4

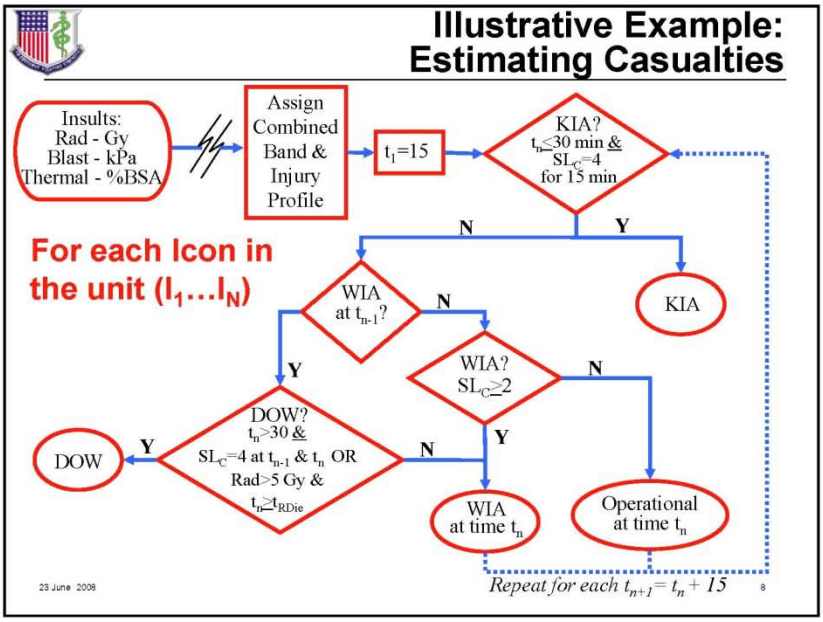

STEPPING THROUGH
A “GAME”
23 June 2008
5

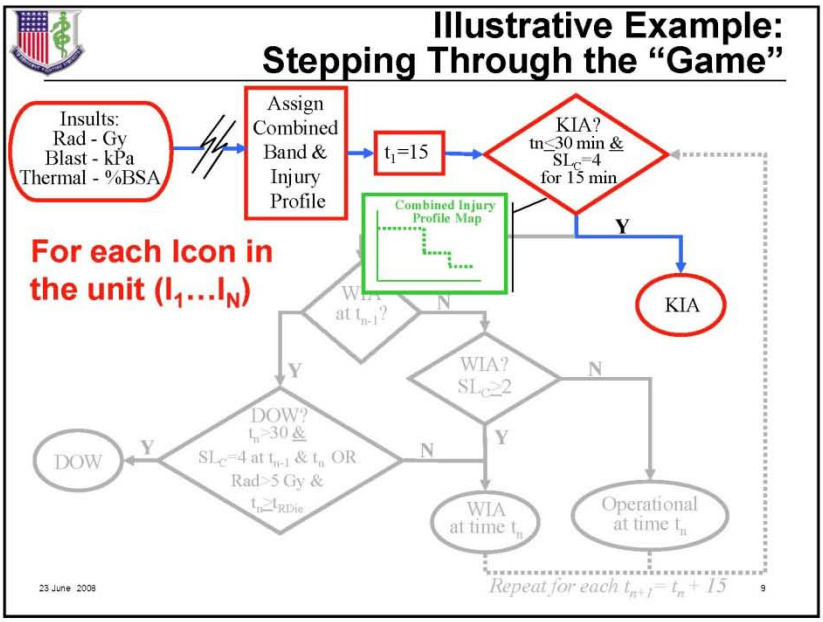
Illustrative Example: User Defined Parameters

- Time to Reach an MTF = **30 minutes**
- Evaluative Time Period (TP_E) = **15 minutes**
- KIA = Severity Level for Combined (SL_C) at **4** for **15 minutes** within first **30 minutes** of the "game"
- WIA = SL_C at **2 or greater**
- DOW = SL_C at 4 for **two** consecutive time periods or satisfy the radiation criteria for DOW after the first **30 minutes** of the "game"
- Reporting Times = **1st hour, 1st day, 2nd day….**
- Total Time = **30 days**

Illustrative Example: Unit Laydown and Attack




Illustrative Example:
Estimating Casualties
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign Combined Band & Injury Profile
t_1=15
KIA?
$t_n \leq 30$ min & $SL_C=4$ for 15 min
N
Y
For each Icon in the unit ($I_1 \ldots I_N$)
WIA at t_{n-1}?
N
Y
KIA
WIA? $SL_C \geq 2$
N
Y
DOW?
$t_n > 30$ &
$SL_C=4$ at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
Y
N
DOW
WIA at time t_n
Operational at time t_n
Repeat for each $t_{n+1} = t_n + 15$
23 June 2008
8


Illustrative Example:
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign Combined Band & Injury Profile
t_1=15
KIA?
$t_n \leq 30$ min & $SL_C=4$ for 15 min
Combined Injury Profile Map
Y
For each Icon in the unit ($I_1 \ldots I_N$)
KIA
WIA at t_{n-1}?
N
Y
WIA? $SL_C \geq 2$
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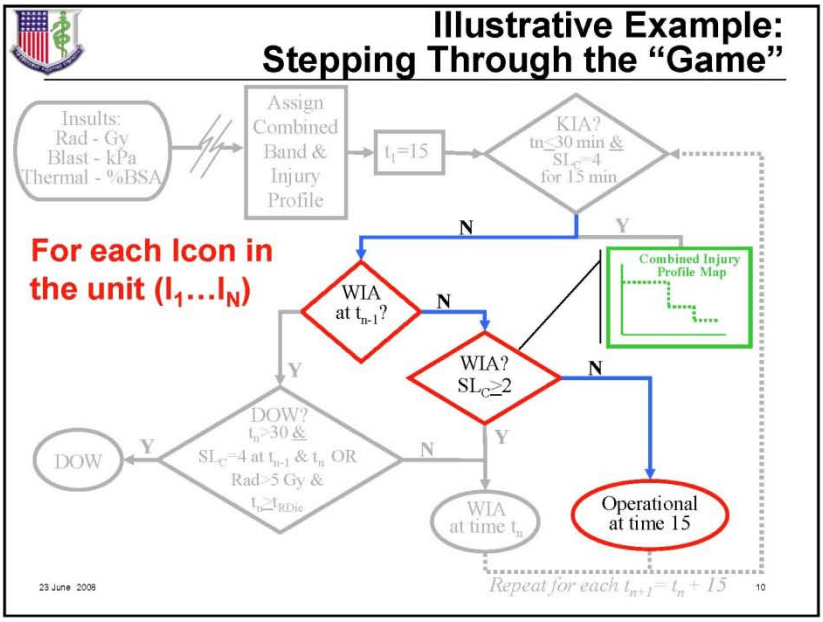
Y
N
DOW
WIA at time t_n
Operational at time t_n
Repeat for each $t_{n+1} = t_n + 15$
23 June 2008
9


Illustrative Example:
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Insults:
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Blast - kPa
Thermal - %BSA
Assign Combined Band & Injury Profile
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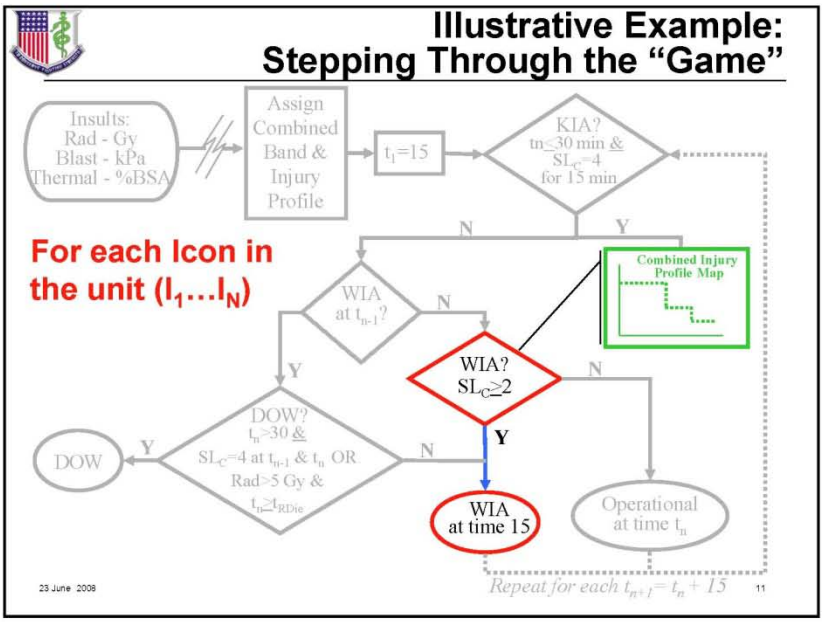
KIA?
tn≤30 min & SL_C=4 for 15 min
N
Y
For each Icon in the unit (I_1…I_N)
WIA at t_{n-1}?
N
Y
Combined Injury Profile Map
WIA? $SL_C \geq 2$
N
Y
DOW?
t_n>30 & SL_C=4 at t_{n-1} & t_n OR Rad>5 Gy & $t_n \geq t_{RDie}$
Y
N
DOW
WIA at time t_n
Operational at time 15
Repeat for each $t_{n+1} = t_n + 15$
23 June 2008
10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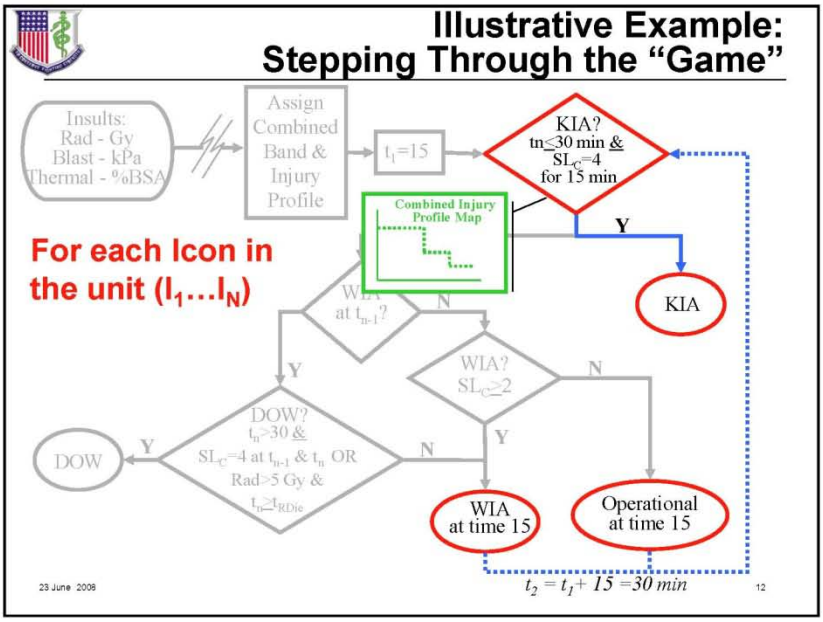
DOW?
t_n>30 & SL_C=4 at t_{n-1} & t_n OR Rad>5 Gy & $t_n \geq t_{RDie}$
Y
N
DOW
WIA at time 15
Operational at time t_n
Repeat for each $t_{n+1} = t_n + 15$
23 June 2008
11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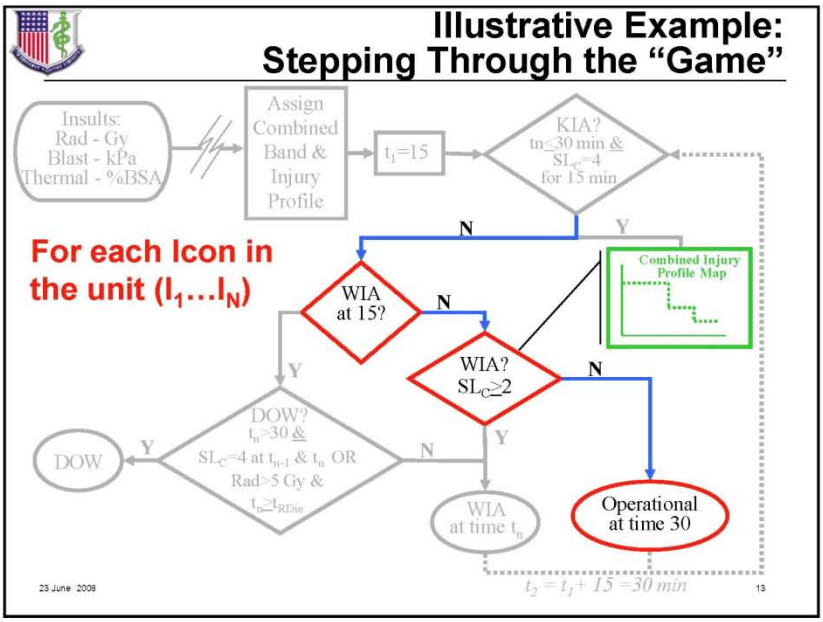
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
tn≤30 min &
SL_C=4
for 15 min
Combined Injury
Profile Map
Y
KIA
For each Icon in
the unit (I_1…I_N)
N
WIA?
SL_C≥2
N
Y
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
Y
DOW
N
Y
WIA
at time 15
Operational
at time 15
23 June 2008
$t_2 = t_1 + 15 = 30$ min
12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Stepping Through the "Game"
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Rad - Gy
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Combined
Band &
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Profile
t_1=15
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tn≤30 min &
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for 15 min
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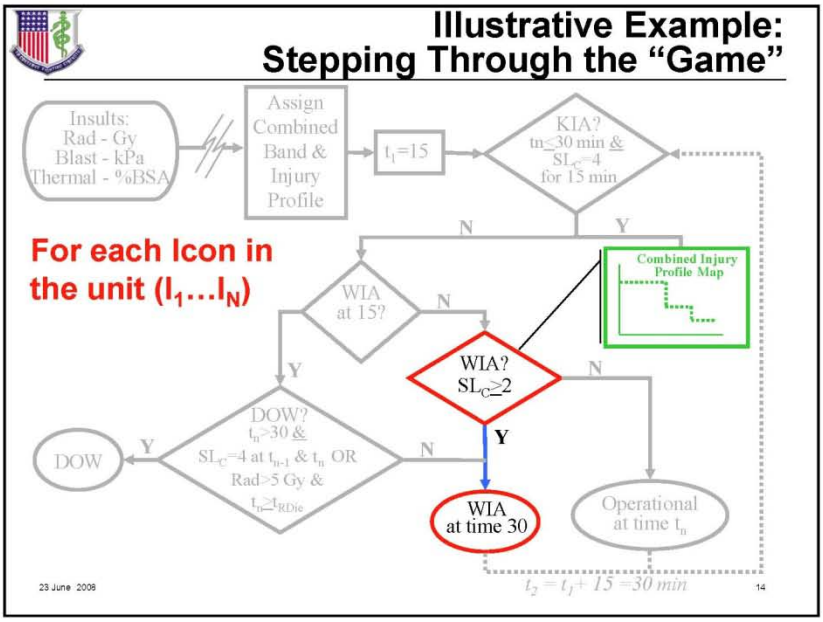
For each Icon in
the unit (I_1…I_N)
WIA
at 15?
N
Combined Injury
Profile Map
WIA?
SL_C≥2
N
Y
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
Y
DOW
N
Y
WIA
at time t_n
Operational
at time 30
23 June 2008
$t_2 = t_1 + 15 = 30$ min
13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Stepping Through the "Game"
Insults:
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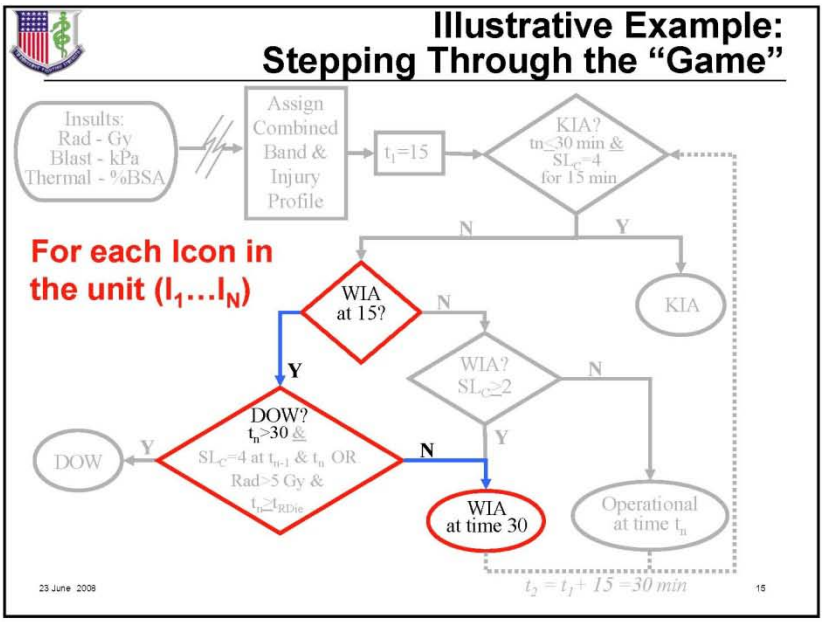
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
$t_n \leq 30$ min &
$SL_C=4$
for 15 min
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
Combined Injury
Profile Map
WIA
at 15?
N
Y
WIA?
$SL_C \geq 2$
N
Y
DOW?
$t_n>30$ &
$SL_C=4$ at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
DOW
Y
N
WIA
at time 30
Operational
at time t_n
23 June 2008
$t_2 = t_1 + 15 = 30$ min
14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Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
$t_n \leq 30$ min &
$SL_C=4$
for 15 min
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
WIA
at 15?
N
KIA
Y
WIA?
$SL_C \geq 2$
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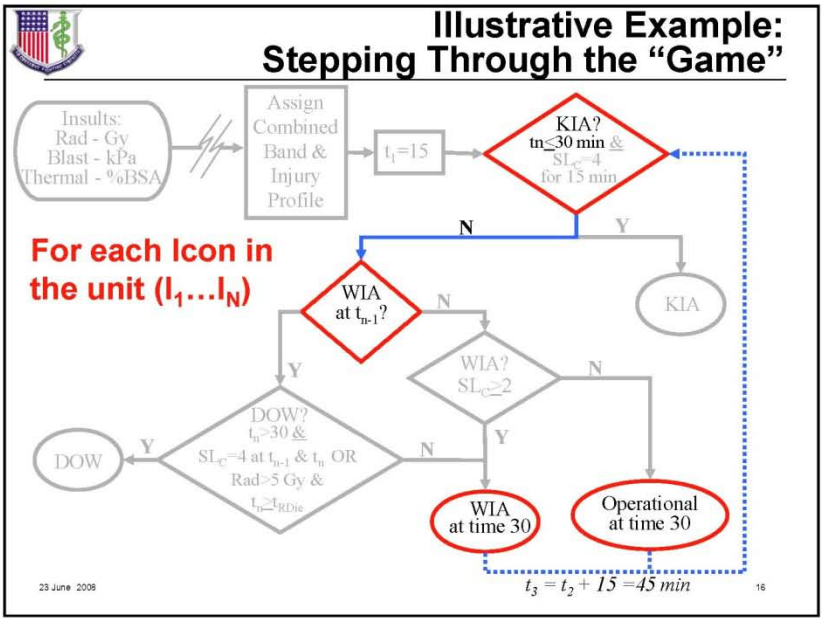
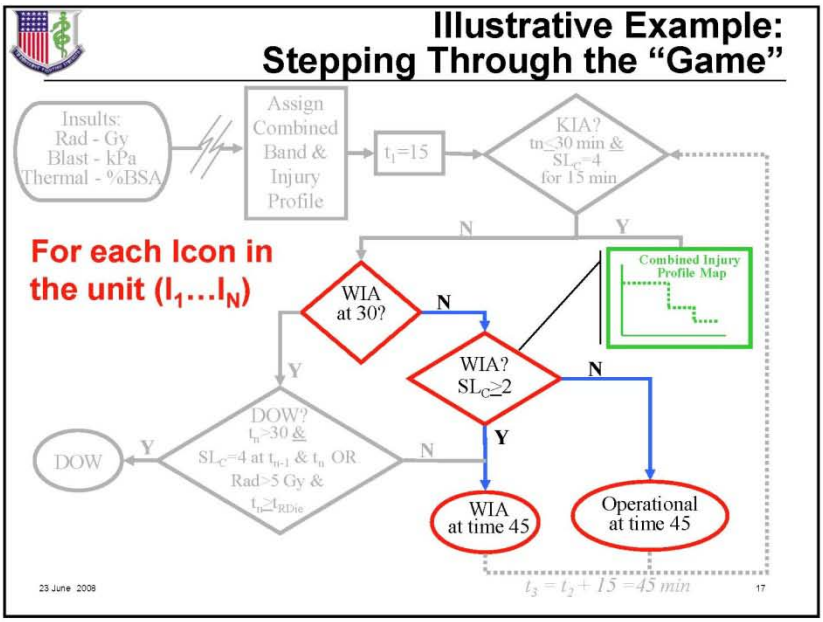
Y
DOW?
$t_n>30$ &
$SL_C=4$ at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
DOW
Y
N
WIA
at time 30
Operational
at time t_n
23 June 2008
$t_2 = t_1 + 15 = 30$ min
15


Illustrative Example:
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
tn≤30 min &
SL_C=4
for 15 min
N
Y
For each Icon in
the unit (I_1…I_N)
WIA
at t_{n-1}?
N
KIA
Y
WIA?
SL_C≥2
N
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
Y
DOW
Y
N
Y
WIA
at time 30
Operational
at time 30
23 June 2008
$t_3 = t_2 + 15 = 45$ min
16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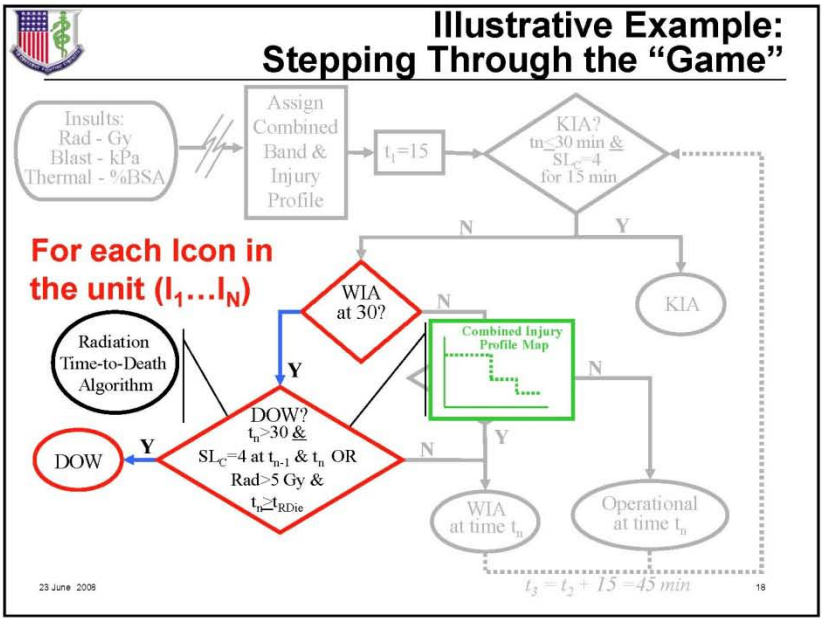
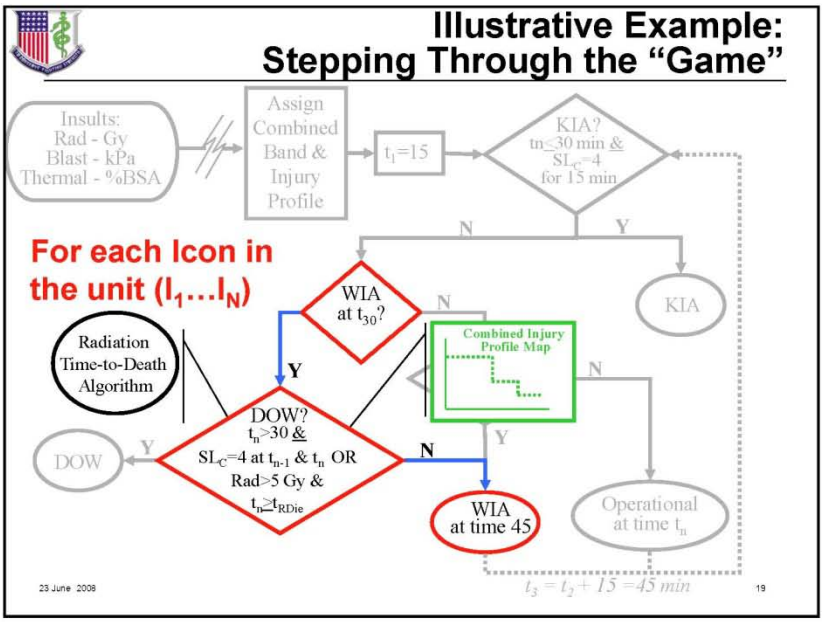
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
tn≤30 min &
SL_C=4
for 15 min
N
Y
For each Icon in
the unit (I_1…I_N)
Combined Injury
Profile Map
WIA
at 30?
N
Y
WIA?
SL_C≥2
N
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
Y
DOW
Y
N
Y
WIA
at time 45
Operational
at time 45
23 June 2008
$t_3 = t_2 + 15 = 45$ min
17


Illustrative Example:
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
tn≤30 min &
SL_C=4
for 15 min
N
Y
KIA
For each Icon in
the unit (I_1…I_N)
WIA
at 30?
N
Y
Combined Injury
Profile Map
N
Y
Radiation
Time-to-Death
Algorithm
DOW
Y
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
N
WIA
at time t_n
Operational
at time t_n
$t_3 = t_2 + 15 = 45$ min
23 June 2008
18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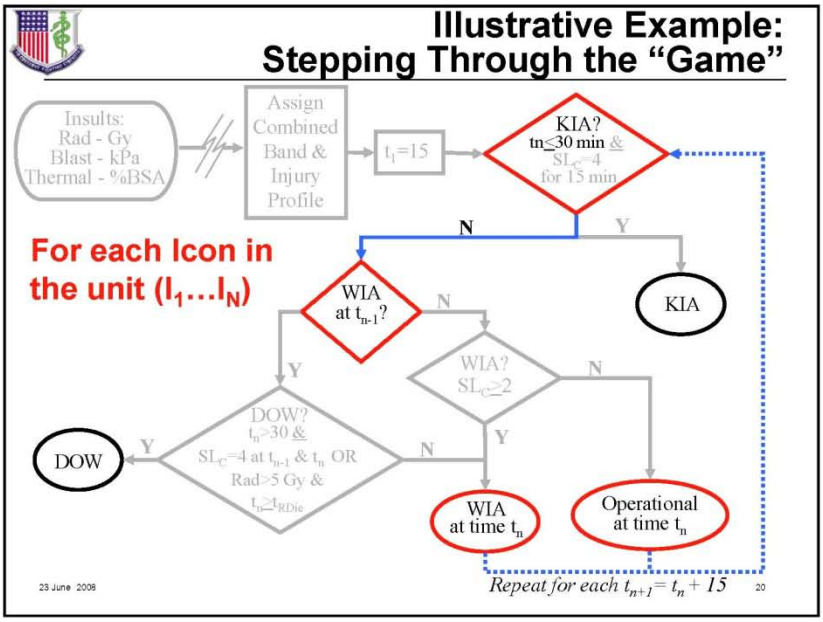
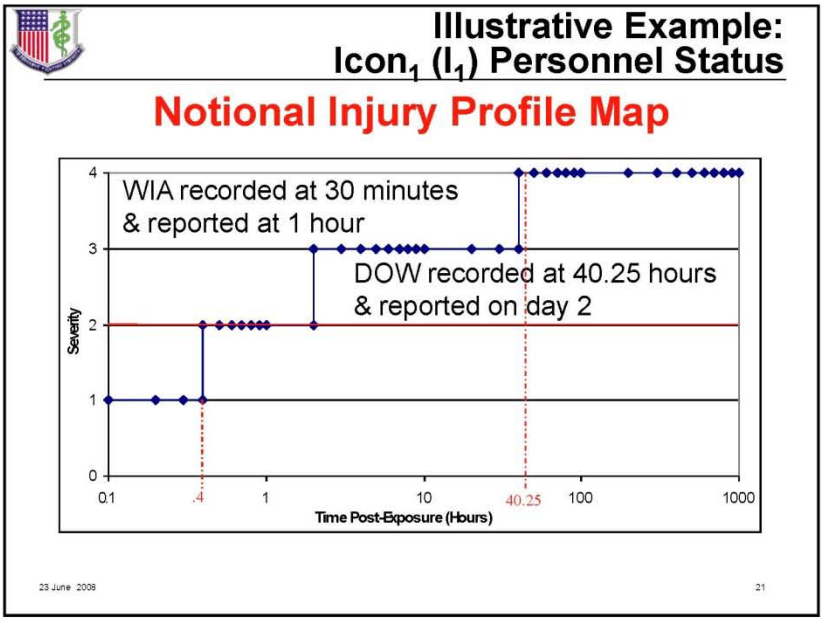
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign
Combined
Band &
Injury
Profile
t_1=15
KIA?
tn≤30 min &
SL_C=4
for 15 min
N
Y
KIA
For each Icon in
the unit (I_1…I_N)
WIA
at t_{30}?
N
Y
Combined Injury
Profile Map
N
Y
Radiation
Time-to-Death
Algorithm
DOW
Y
DOW?
t_n>30 &
SL_C=4 at t_{n-1} & t_n OR
Rad>5 Gy &
$t_n \geq t_{RDie}$
N
WIA
at time 45
Operational
at time t_n
$t_3 = t_2 + 15 = 45$ min
23 June 2008
19


Illustrative Example:
Stepping Through the "Game"
Insults:
Rad - Gy
Blast - kPa
Thermal - %BSA
Assign Combined Band & Injury Profile
t_1=15
KIA?
$t_n \leq 30$ min & SL_C=4 for 15 min
N
Y
For each Icon in the unit ($I_1 \ldots I_N$)
WIA at t_{n-1}?
N
KIA
Y
WIA? $SL_C \geq 2$
N
Y
DOW? t_n>30 & SL_C=4 at t_{n-1} & t_n OR Rad>5 Gy & $t_n \geq t_{RDie}$
Y
N
DOW
WIA at time t_n
Operational at time t_n
Repeat for each $t_{n+1} = t_n + 15$
23 June 2008
20


Illustrative Example:
Icon$_1$ (I_1) Personnel Status
Notional Injury Profile Map
WIA recorded at 30 minutes & reported at 1 hour
DOW recorded at 40.25 hours & reported on day 2
Severity
0
1
2
3
4
0.1
.4
1
10
40.25
100
1000
Time Post-Exposure (Hours)
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Illustrative Example: Results

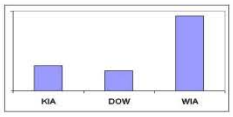
During the course of the "game" the model saved the following data:

- KIA at the recorded time
- WIA at the recorded time
- DOW at the recorded time

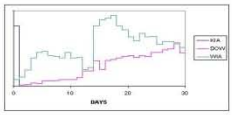
Illustrative Example: Results

Examples of Output Presentations:

- Personnel Status Totals:



- Personnel Status Differentials:



These graphs are notional only

Questions?

Contact

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Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
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ccurling@ida.org 703-578-2814
rzirkle@ida.org 703-845-2038
ddisrael@ida.org 703-845-6685

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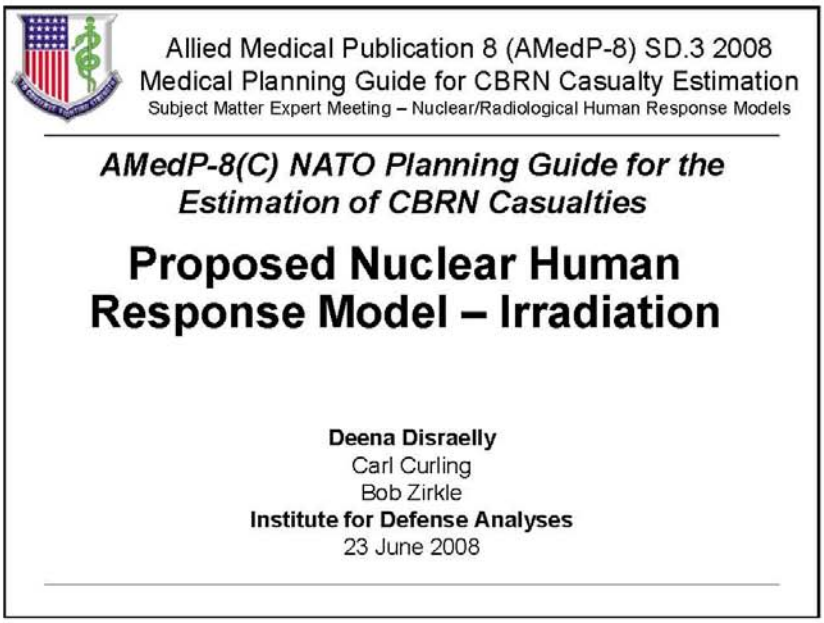
F. Proposed Nuclear Human Response Model – Irradiation – *Briefing*

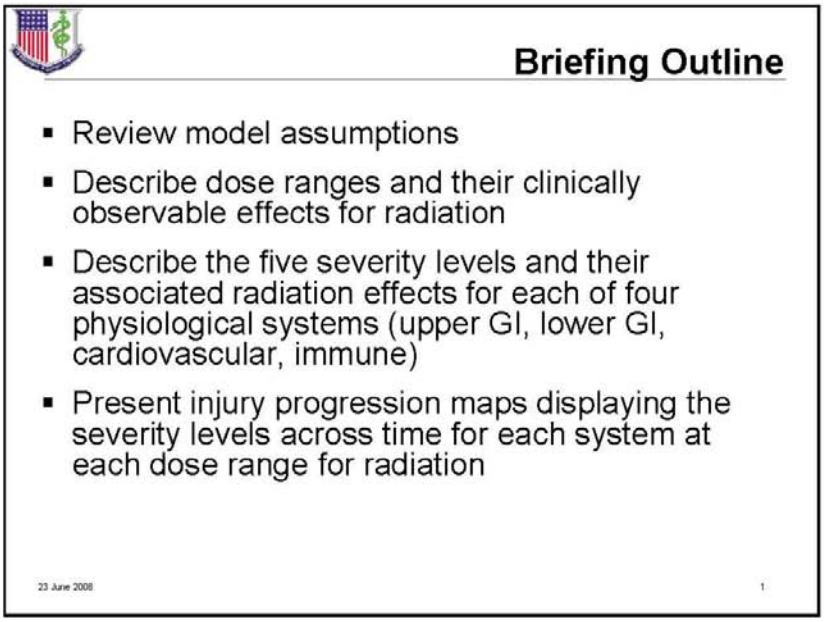


Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties

Proposed Nuclear Human Response Model – Irradiation

Deena Disraelly
Carl Curling
Bob Zirkle
Institute for Defense Analyses
23 June 2008



Briefing Outline

- Review model assumptions
- Describe dose ranges and their clinically observable effects for radiation
- Describe the five severity levels and their associated radiation effects for each of four physiological systems (upper GI, lower GI, cardiovascular, immune)
- Present injury progression maps displaying the severity levels across time for each system at each dose range for radiation

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MODEL ASSUMPTIONS

Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related effects (signs and symptoms)
  - Dose-related effects apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- All cumulative doses and insults are the result of prompt, instantaneous, simultaneous nuclear insults
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted
  - Human response for the entire exposed population begins simultaneously immediately following the nuclear detonation

Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization

RADIATION DOSE BANDS

Radiation Dose Range

Dose Range (Gy)	Description
0 – 0.75	No observable effect
0.75 – 3	A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is >90 percent unless there are other injuries
3 – 5.3	Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible lethality
5.3 – 8.3	Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries they may die within 2 weeks
> 8.3	Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2-3 weeks; with other injuries they may die within 2 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1-2.5 weeks or if other injuries are also present, patients may die within 6 days

Derived from NATO. *AMedP-8. Op. cit.* p. 3-9; and NATO. *STANAG 2038.*

RADIATION SIGNS & SYMPTOMS SEVERITY LEVELS & MAPS

Severity Definitions

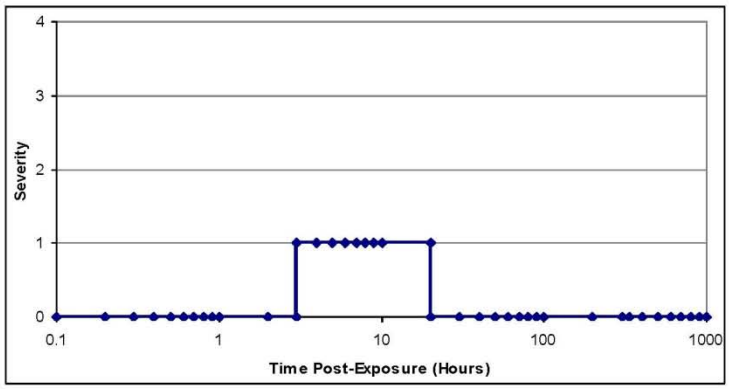
	Degrees	Description
0	N.O.E.	No observable effect
1	Mild	Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms
2	Moderate	Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission
3	Severe	Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms
4	Very Severe	Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms

Signs/Symptoms Severities

Signs / Symptoms Severity	Upper GI Signs/Symptoms	Lower GI Signs/Symptoms
0	No observable effect	No observable effect
1	Upset stomach and nausea; watering mouth and frequent swallowing to avoid vomiting	Abdominal pain or cramps; occasional diarrhea and uncomfortable urge to defecate
2	Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting	Frequent diarrhea and cramps; continuing defecation
3	Protracted or continued vomiting, including dry heaves	Uncontrollable diarrhea and urination; painful cramps
4		

Radiation S/S Map for Dose Range of 0.75–3 Gy

UPPER GI



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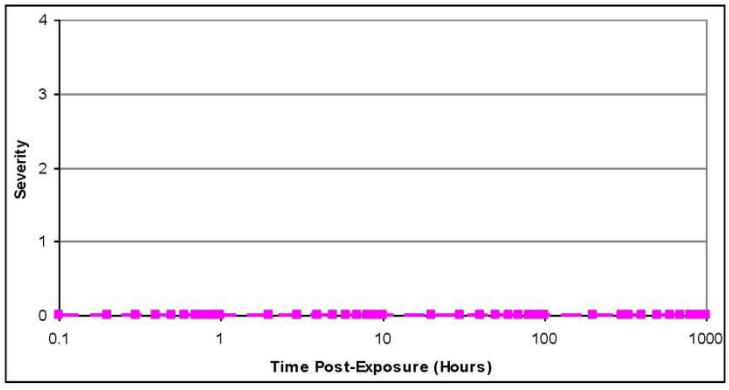
Radiation S/S Map for Dose Range of 0.75–3 Gy

LOWER GI



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Signs/Symptoms Severities

Signs / Symptoms Severity	Cardiovascular Signs/Symptoms	Immune Symptoms
0	No observable effect	No observable effect
1	Slight feeling of light headedness	Slight fever and headache
2	Unsteadiness upon standing quickly	Aching joints; fever; lack of appetite; sores in mouth/throat
3	Severe dizziness; faints upon standing quickly; may have difficulty stopping any bleeding	High fever results in shakes, chills and aches all over
4	Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain	Delirium from fever; overwhelming infections

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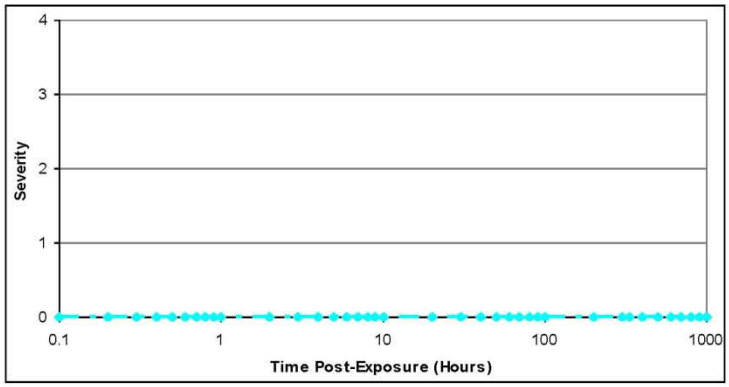
Radiation S/S Map for Dose Range of 0.75–3 Gy

CARDIOVASCULAR



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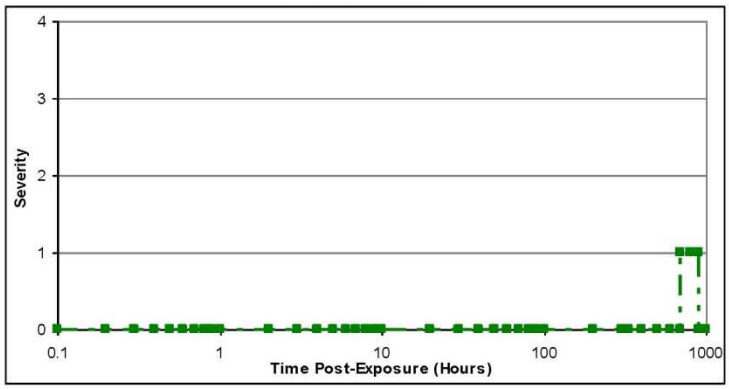
Radiation S/S Map for Dose Range of 0.75–3 Gy

IMMUNE



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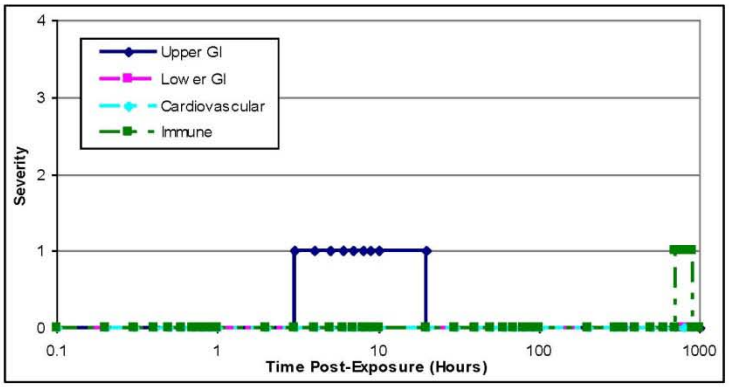
Radiation Injury Progression Map for Dose Range of 0.75–3 Gy



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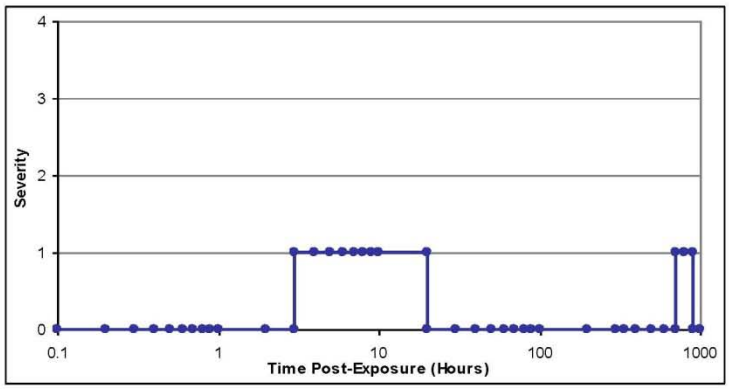
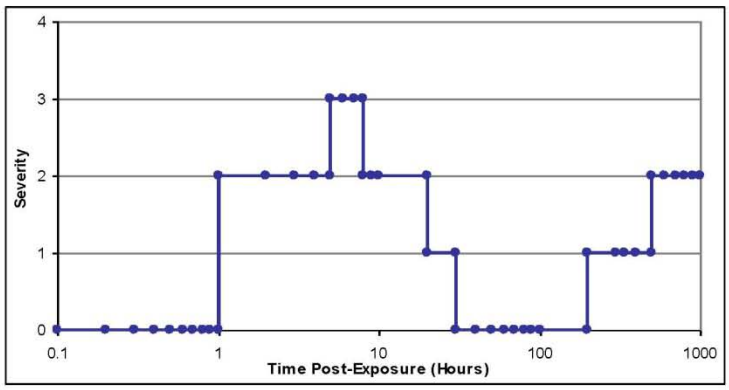
Radiation Injury Profile Map for Dose Range of 0.75–3 Gy



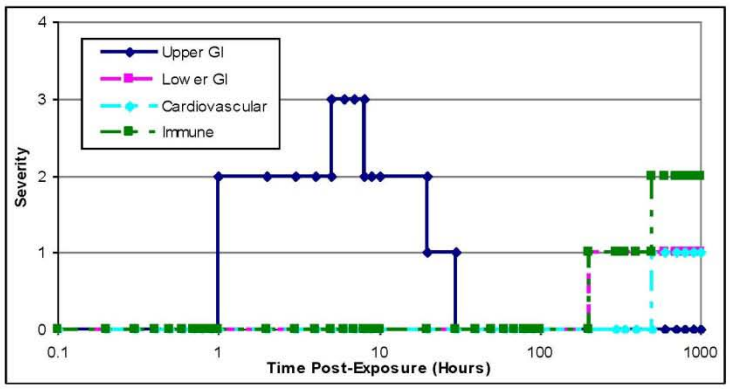
23 June 2008 16

Radiation Injury Profile Map for Dose Range of 3–5.3 Gy



23 June 2008 17

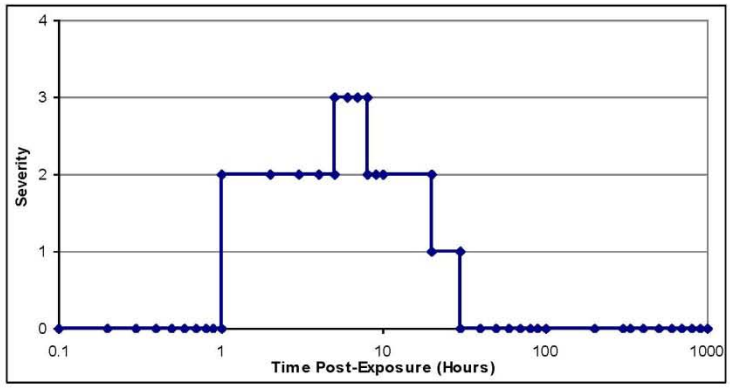
Radiation Injury Progression Map for Dose Range of 3–5.3 Gy



23 June 2008 18

Radiation S/S Map for Dose Range of 3–5.3 Gy

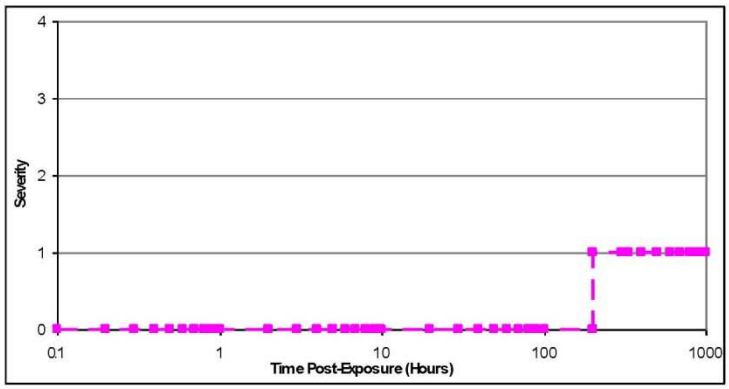
UPPER GI



23 June 2008 19

Radiation S/S Map for Dose Range of 3–5.3 Gy

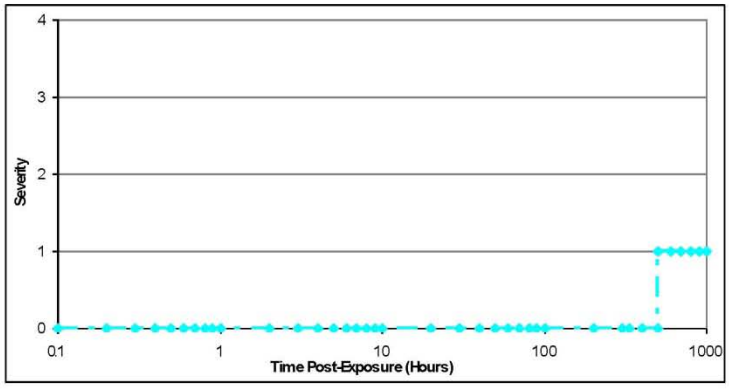
LOWER GI



23 June 2008 20

Radiation S/S Map for Dose Range of 3–5.3 Gy

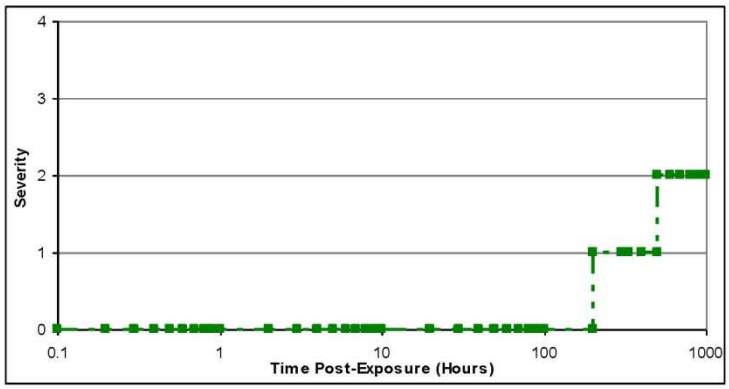
CARDIOVASCULAR



23 June 2008 21

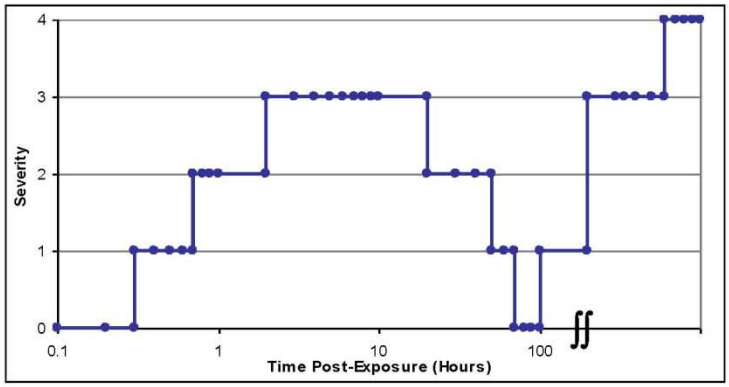
Radiation S/S Map for Dose Range of 3–5.3 Gy

IMMUNE



23 June 2008 22

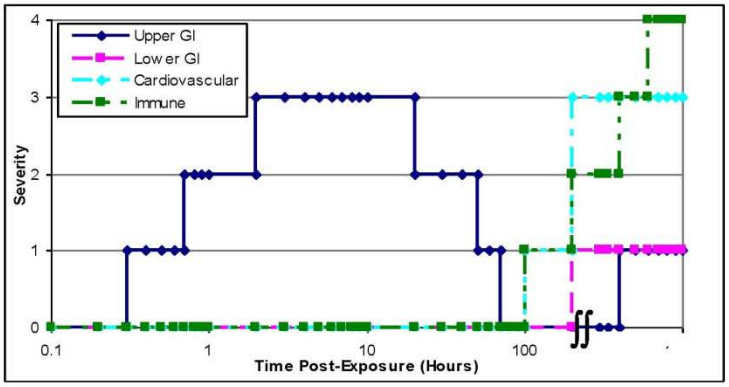
Radiation Injury Profile Map for Dose Range of 5.3–8.3 Gy



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

23 June 2008 23

Radiation Injury Progression Map for Dose Range of 5.3–8.3 Gy

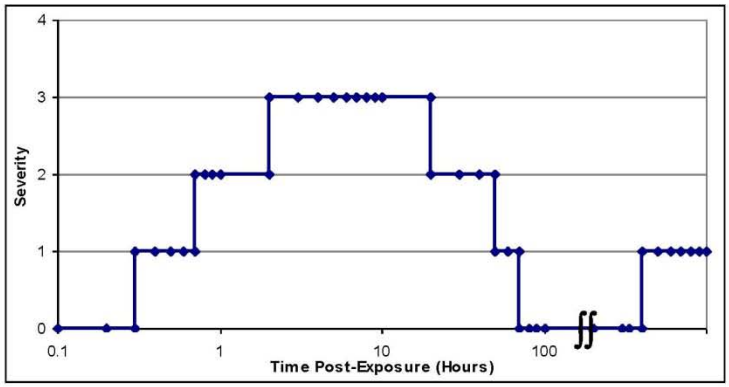


For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

23 June 2008 24

Radiation S/S Map for Dose Range of 5.3–8.3 Gy

UPPER GI

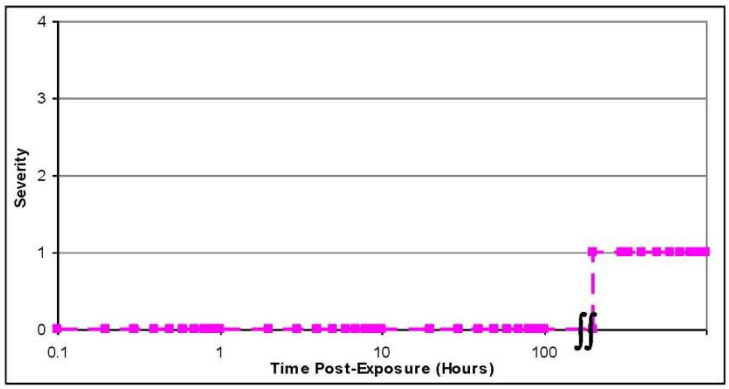


For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

23 June 2008 25

Radiation S/S Map for Dose Range of 5.3–8.3 Gy

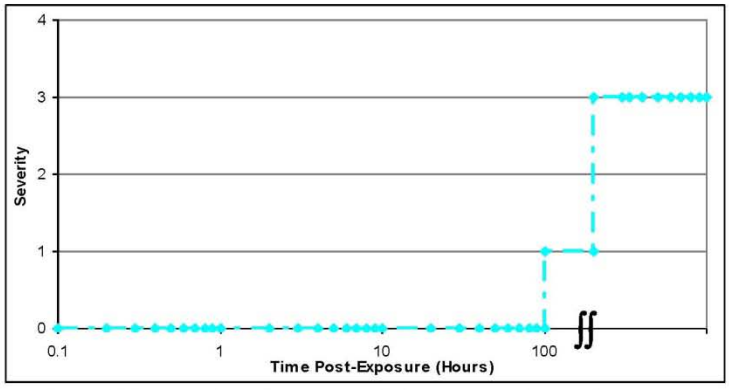
LOWER GI



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation S/S Map for Dose Range of 5.3–8.3 Gy

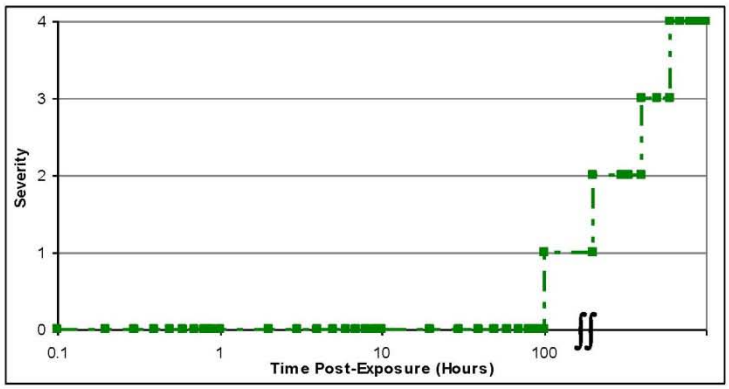
CARDIOVASCULAR



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

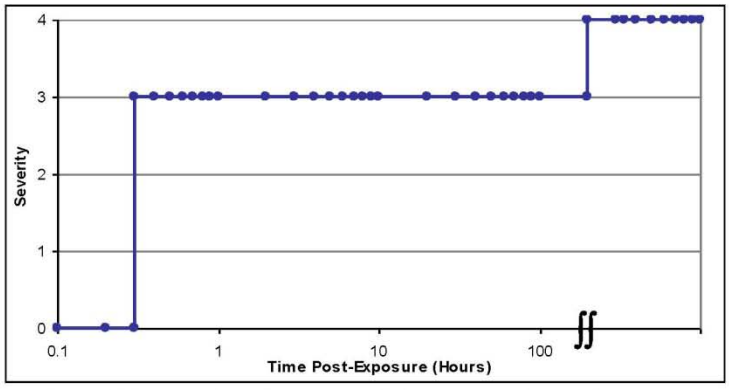
Radiation S/S Map for Dose Range of 5.3–8.3 Gy

IMMUNE



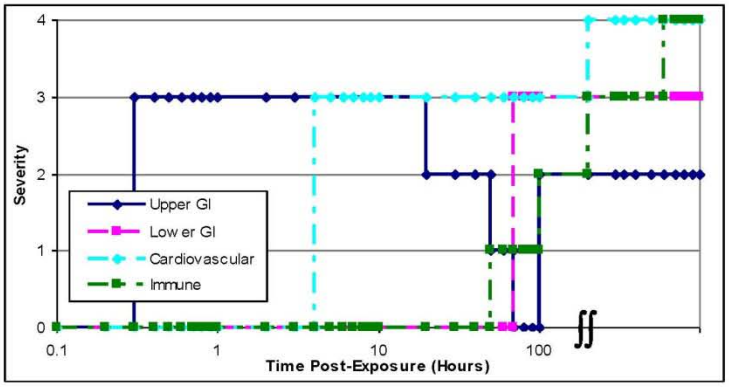
For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation Injury Profile Map for Dose Range of > 8.3 Gy



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

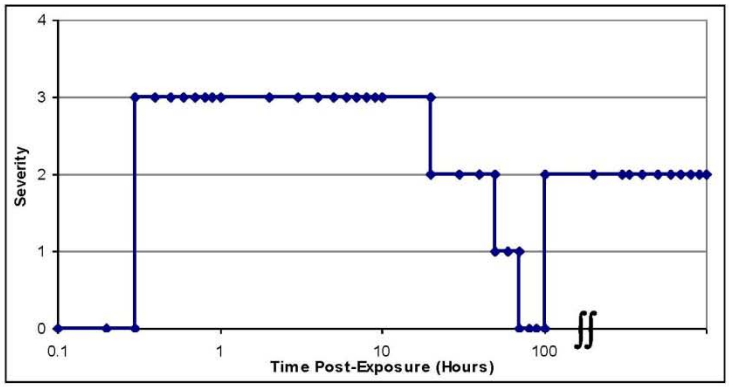
Radiation Injury Progression Map for Dose Range of > 8.3 Gy



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation S/S Map for Dose Range of > 8.3 Gy

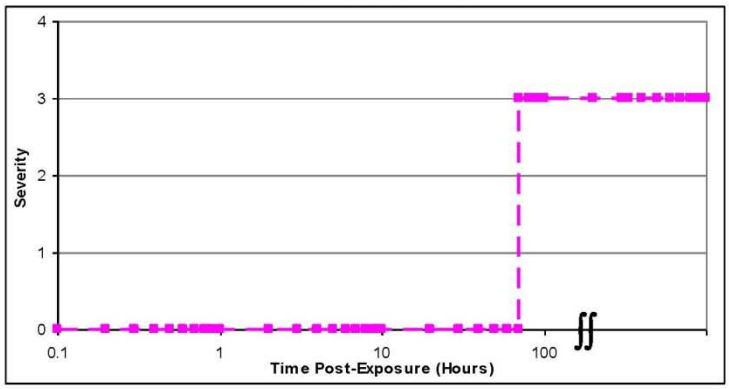
UPPER GI



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation S/S Map for Dose Range of > 8.3 Gy

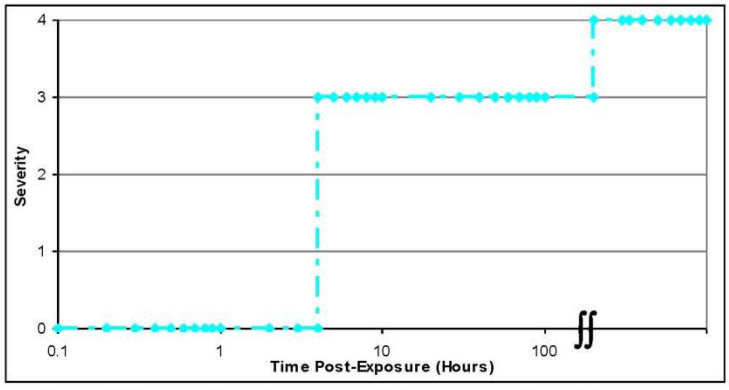
LOWER GI



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation S/S Map for Dose Range of > 8.3 Gy

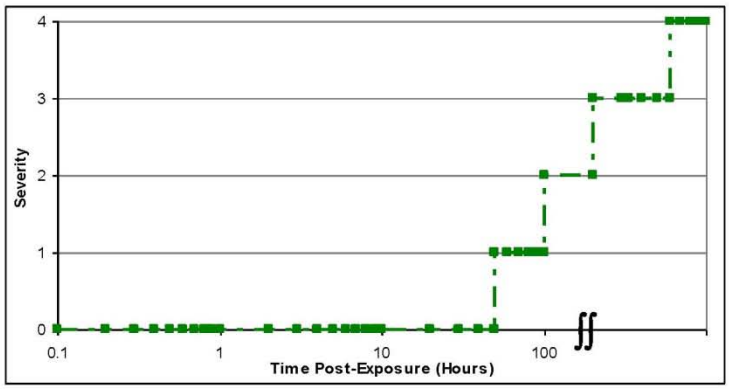
CARDIOVASCULAR



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

Radiation S/S Map for Dose Range of > 8.3 Gy

IMMUNE



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

DOW: SPECIAL CONSIDERATION FOR RADIATION

Special Consideration for Radiation

- Propose to calculate radiation-induced time-to-death
  - Feasible because data potentially exists to support a calculation
    - Time to Death as a function of radiation dose has been (uniquely) well characterized in animal models and human experience.
  - Allows for a deterministic calculation of dose-based time-to-death
- Multiple possible methods for estimating radiation-induced time-to-death, including but not limited to
  - Intermediate dose program (IDP) methodology
  - Radiation induced performance decrement (RIPD) methodology
  - Anno radiation-induced time-to-death curve

Are there other methodologies which should be considered?

Radiation-Induced Time-to-Death: RIPD

- RIPD (Radiation Induced Performance Decrement) code*
  - The functional form of the equation used to estimate time-to-death in RIPD is:

$$T_{Death} = \frac{P_1}{P_2 + D^{P_3}} + \frac{P_4}{P_5 + D^{P_6}}$$

Where T_{Death} is the time to death, in hours
D is the midline tissue dose, in cGy
The values of the coefficients found to provide a good fit to the data are:

$P_1 = 8.789 \times 10^8$ $P_4 = 1.9866 \times 10^6$
$P_2 = 1.923 \times 10^6$ $P_5 = 5.8218 \times 10^3$
$P_3 = 2.4489$ $P_6 = 1.2$

*Anno, G. H., G. E. McClellan, and M. A. Dore, *Protracted Radiation-Induced Performance Decrement*, Vol. 1: *Model Development*, DNA-TR-95-117-V1, Defense Nuclear Agency, Washington, DC, May 1996.

Radiation-Induced Time-to-Death: RIPD

- RIPD (Radiation Induced Performance Decrement) code*
  - The functional form of the equation used to estimate time-to-death in RIPD is:

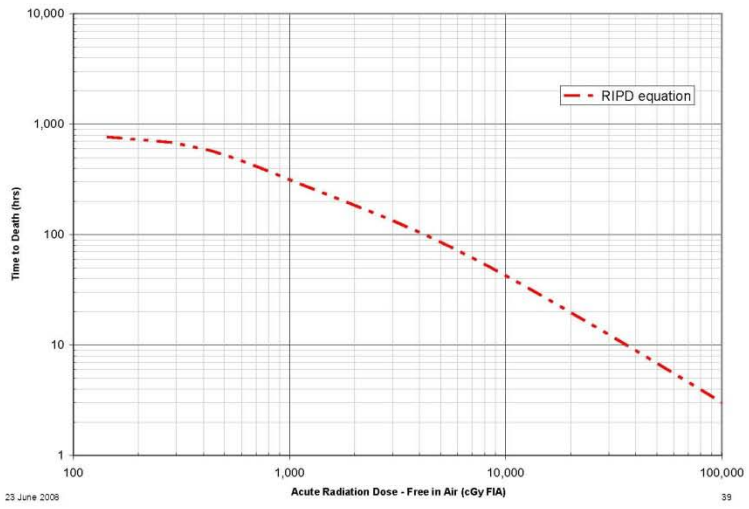
$$T_{Death} = \frac{P_1}{P_2 + \left(D \cdot 0.7 \cdot 100\right)^{P_3}} + \frac{P_4}{P_5 + \left(D \cdot 0.7 \cdot 100\right)^{P_6}}$$

Where T_{Death} is the time to death, in hours
D is the free in air dose, in Gy
The values of the coefficients found to provide a good fit to the data are:

$P_1 = 8.789 \times 10^8$ $P_4 = 1.9866 \times 10^6$
$P_2 = 1.923 \times 10^6$ $P_5 = 5.8218 \times 10^3$
$P_3 = 2.4489$ $P_6 = 1.2$

*Anno, G. H., G. E. McClellan, and M. A. Dore, *Protracted Radiation-Induced Performance Decrement*, Vol. 1: *Model Development*, DNA-TR-95-117-V1, Defense Nuclear Agency, Washington, DC, May 1996.

Radiation-Induced Time-to-Death: RIPD



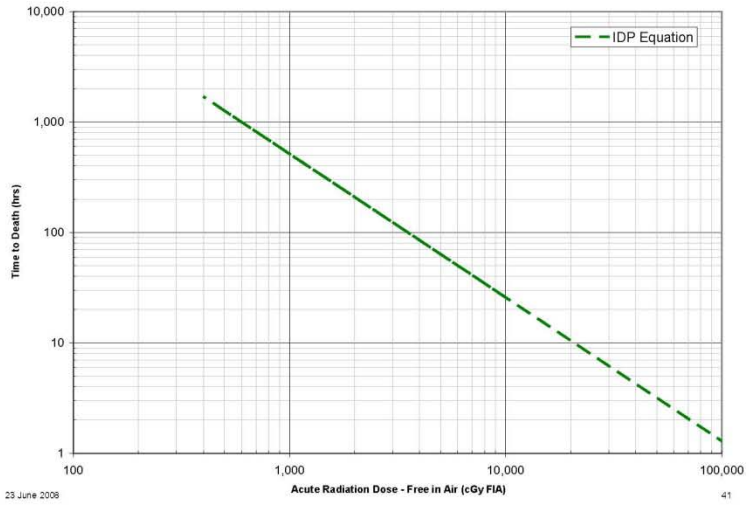
Radiation-Induced Time-to-Death: IDP

- Defense Nuclear Agency's Intermediate Dose Program (derived)
  - Expressed in doctrine in Figure B-21 of Personnel Risk and Casualty Criteria for Nuclear Weapon Effects (PRCC, 1999)
  - Approximated as:

$$T_{Death} = 4.1\text{x}10^{6} \cdot \ D \cdot 100^{\ -1.3}$$

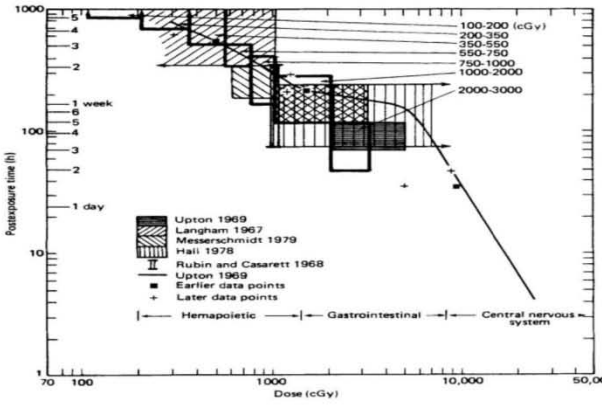
Where T_{Death} is the time to death, in hours
D is the dose, in Gy

Radiation-Induced Time-to-Death: IDP



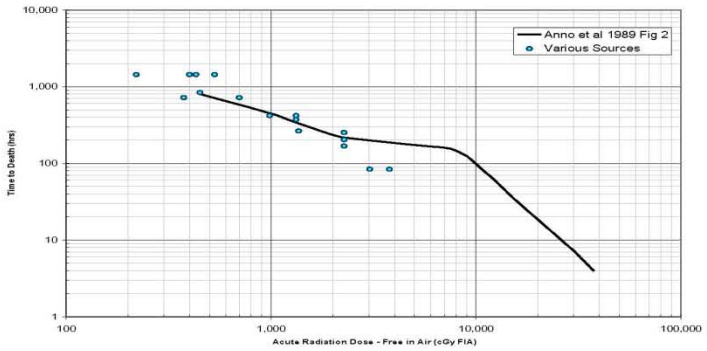
Radiation-Induced Time-to-Death: Anno

- George Anno, et. al. (1989) illustrated multiple different estimates of radiation-induced time-to-death and acute radiation syndromes
  - Included is a curve from Upton (1969) illustrating time-to-death as a function of acute radiation dose



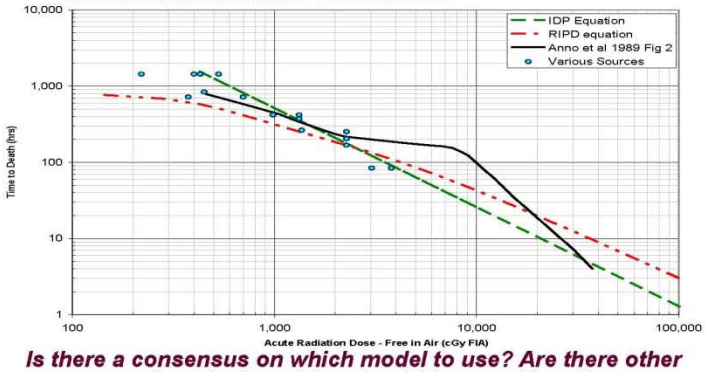
Radiation-Induced Time-to-Death: Upton

- Extracting the Upton curve and adding additional median lethal dose values yields:



Radiation-Induced Time-to-Death

- Propose to calculate radiation-induced time-to-death
  - Intermediate dose program (IDP) methodology
  - Radiation induced performance decrement (RIPD) methodology
  - Anno radiation-induced time-to-death curve



Is there a consensus on which model to use? Are there other methodologies which should be considered?

Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

Questions?

Contact

Carl Curling, Sc.D. Deena Disraelly Robert Zirkle, PhD

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Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

ccurling@ida.org	ddisrael@ida.org	rzirkle@ida.org
703-578-2814	703-845-6685	703-845-2038

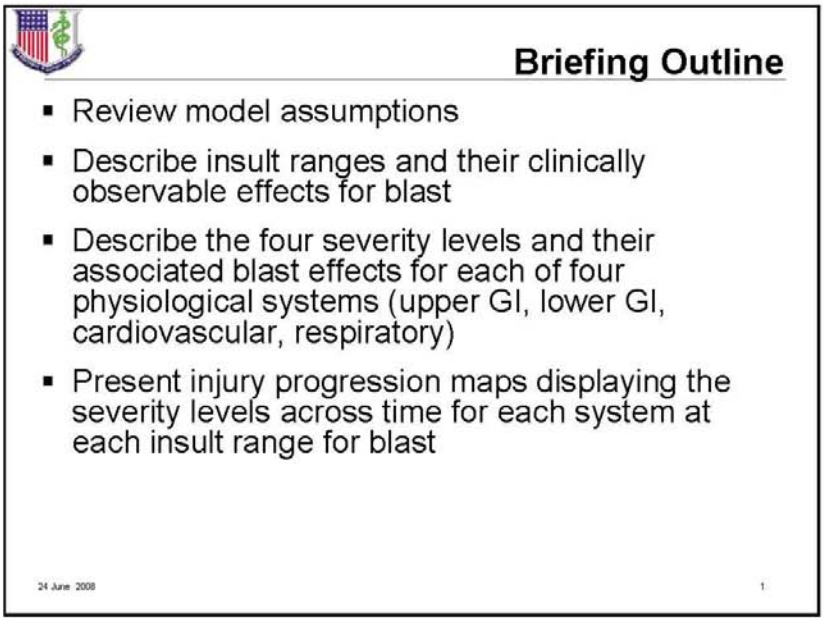
G. Proposed Nuclear Human Response Model – Blast – *Briefing*

Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties

Proposed Nuclear Human Response Model – Blast

Robert Zirkle
Carl Curling
Deena Disraelly
Institute for Defense Analyses
24 June 2008



Briefing Outline

- Review model assumptions
- Describe insult ranges and their clinically observable effects for blast
- Describe the four severity levels and their associated blast effects for each of four physiological systems (upper GI, lower GI, cardiovascular, respiratory)
- Present injury progression maps displaying the severity levels across time for each system at each insult range for blast

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MODEL ASSUMPTIONS

Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related effects (signs and symptoms)
  - Dose-related effects apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- Human response is modeled as primary response to prompt, instantaneous insults
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted
  - Human response for the entire exposed population begins simultaneously immediately following the nuclear detonation

Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization
- Blast assumption:
  - Injuries due to dynamic pressure effects are not included

BLAST INSULT RANGE BANDS

Blast Insult Range

Exp. Range kPa	Description
< 50	No observable effect
50 – 140	50% eardrum rupture; threshold lung damage; threshold gastrointestinal damage
140 – 240	50% burdening level (BD_{50}) lung damage; 90% burdening level (BD_{90}) tympanic membrane rupture
240 – 290	90% burdening level (BD_{90}) lung damage; 10% fatalities (LD_{10})
> 290	50% fatalities (LD_{50})

Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

BLAST SYSTEMS
SEVERITY LEVELS & MAPS

Severity Definitions

	Degrees	Description
0	N.O.E.	No observable effect
1	Mild	Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms
2	Moderate	Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission
3	Severe	Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms
4	Very Severe	Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms

Sign/Symptoms Severities

Signs / Symptoms Severity	Upper GI Signs/Symptoms	Lower GI Signs/Symptoms
0	No observable effect	No observable effect
1	Upset stomach and nausea; watering mouth and frequent swallowing to avoid vomiting	Abdominal pain or cramps; occasional diarrhea and uncomfortable urge to defecate
2	Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting	Frequent diarrhea and cramps; continuing defecation
3	Protracted or continued vomiting, including dry heaves	Uncontrollable diarrhea and urination; painful cramps
4	Rigid belly and extreme abdominal pain+	

+ Upper gastrointestinal signs and symptoms at severity level 4—Very Severe—apply only to blast-induced injuries

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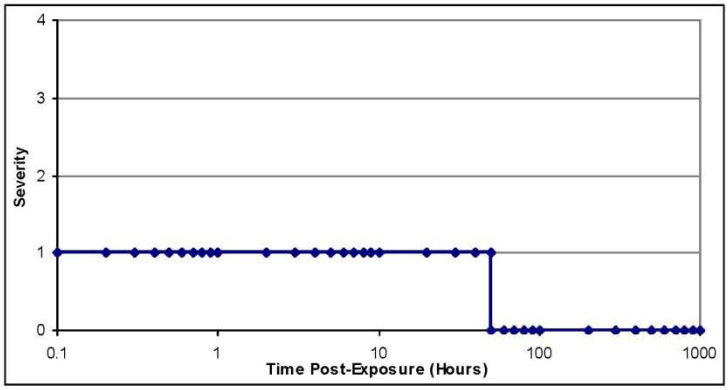
Blast S/S Map for Insult Range of 50–140 kPa

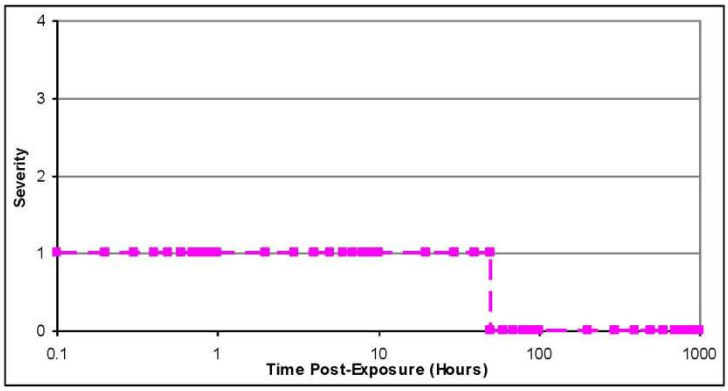
UPPER GI



24 June 2008 10

Blast S/S Map for Insult Range of 50–140 kPa

LOWER GI



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Signs & Symptoms Severities

Signs / Symptoms Severity	Cardiovascular Signs/Symptoms	Respiratory Signs/Symptoms
0	No observable effect	No observable effect
1	Slight feeling of light headedness	Mild shortness of breath
2	Unsteadiness upon standing quickly	Frank shortness of breath, respiratory congestion, non-productive cough
3	Severe dizziness; faints upon standing quickly; may have difficulty stopping any bleeding;	Air hunger; labored breathing; breathing sporadically stops and starts; hemoptysis (spits up blood)
4	Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain	Breathing stops completely or struggling to breathe; cyanosis (skin has a purple or blue color); prostration

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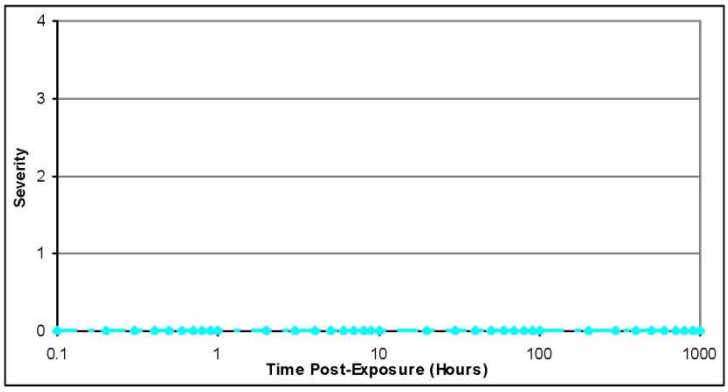
Blast S/S Map for Insult Range of 50–140 kPa

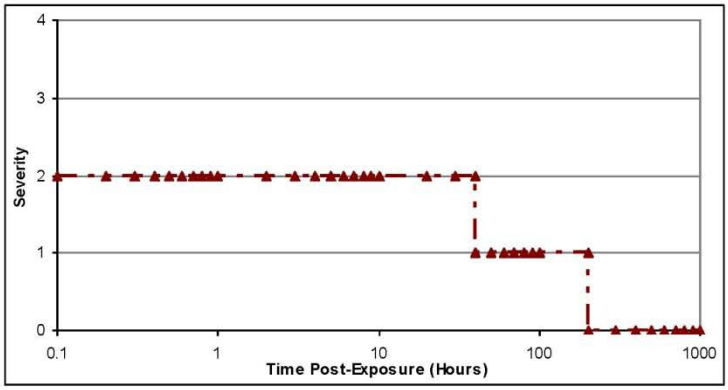
CARDIOVASCULAR



24 June 2008 13

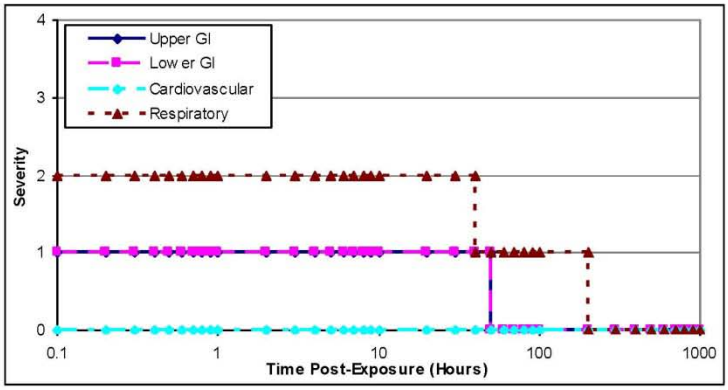
Blast S/S Map for Insult Range of 50–140 kPa

RESPIRATORY



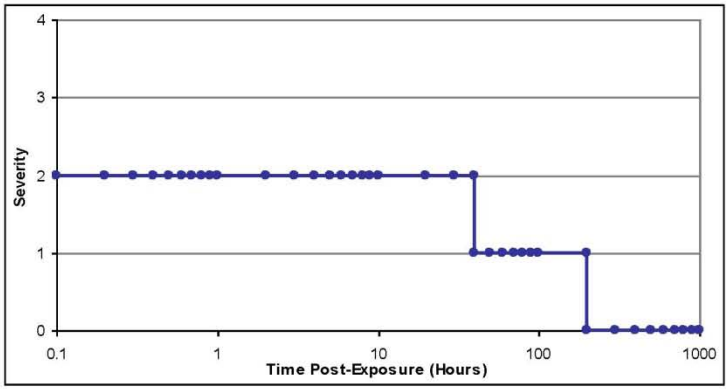
24 June 2008 14

Blast Injury Progression Map for Insult Range of 50–140 kPa



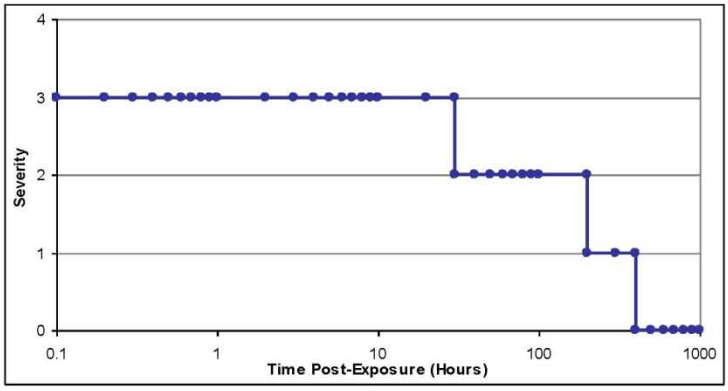
24 June 2008 15

Blast Injury Profile Map for Insult Range of 50–140 kPa



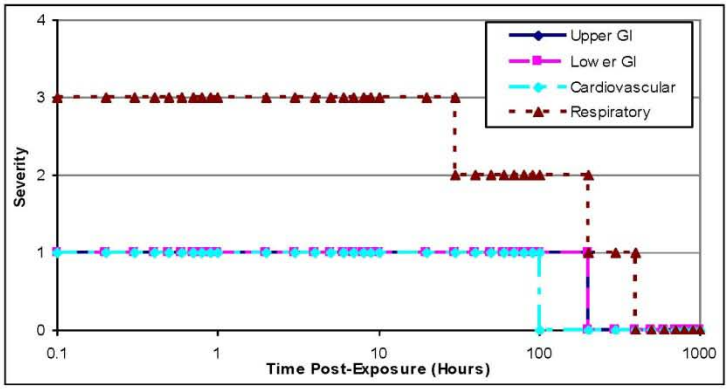
24 June 2008 16

Blast Injury Profile Map for Insult Range of 140–240 kPa



24 June 2008 17

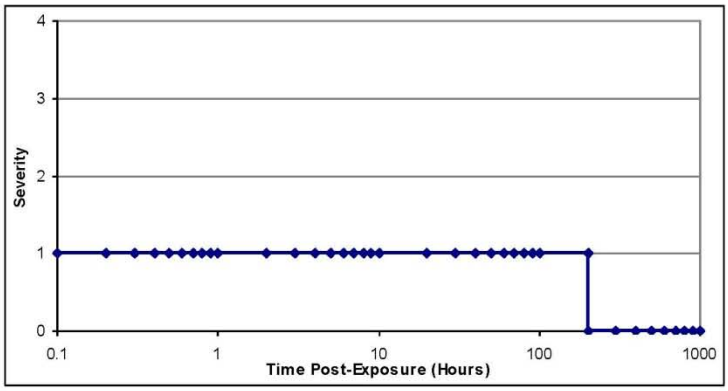
Blast Injury Progression Map for Insult Range of 140–240 kPa



24 June 2008 18

Blast S/S Map for Insult Range of 140–240 kPa

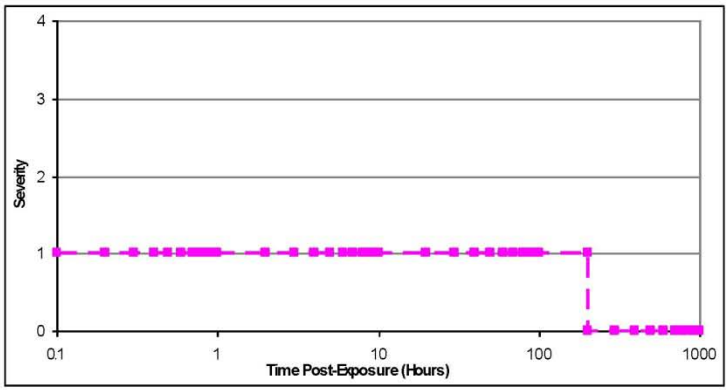
UPPER GI



24 June 2008 19

Blast S/S Map for Insult Range of 140–240 kPa

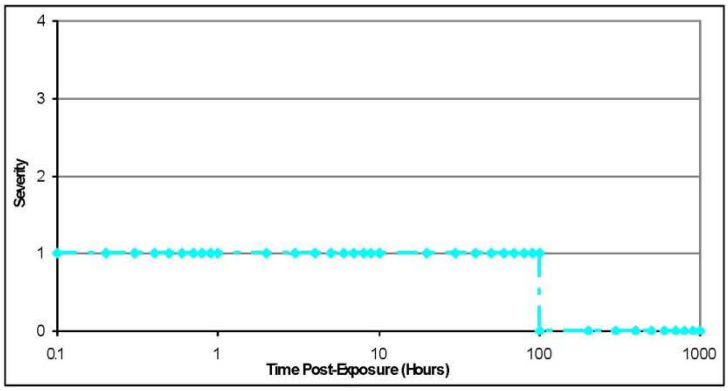
LOWER GI



24 June 2008 20

Blast S/S Map for Insult Range of 140–240 kPa

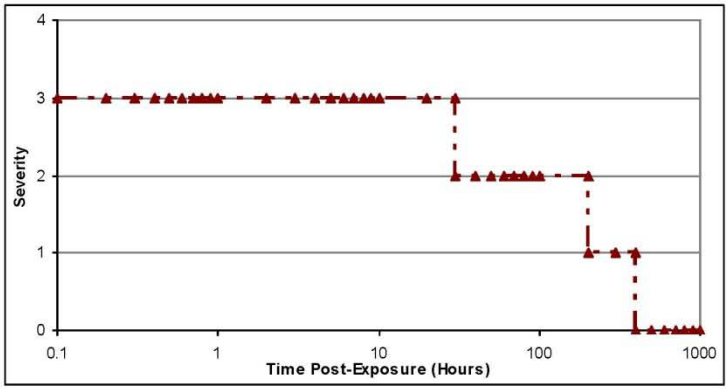
CARDIOVASCULAR



24 June 2008 21

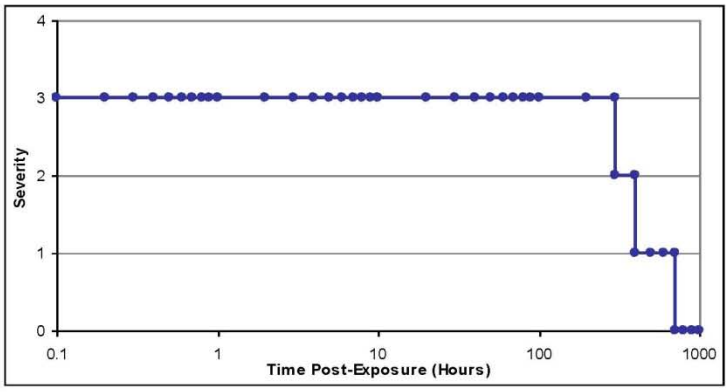
Blast S/S Map for Insult Range of 140–240 kPa

RESPIRATORY



24 June 2008 22

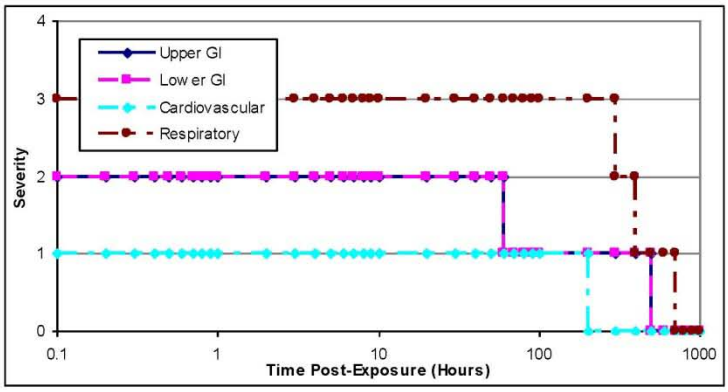
Blast Injury Profile Map for Insult Range of 240–290 kPa



Note: This graphs differs from the one found in the Blast read-ahead

24 June 2008 23

Blast Injury Progression Map for Insult Range of 240–290 kPa

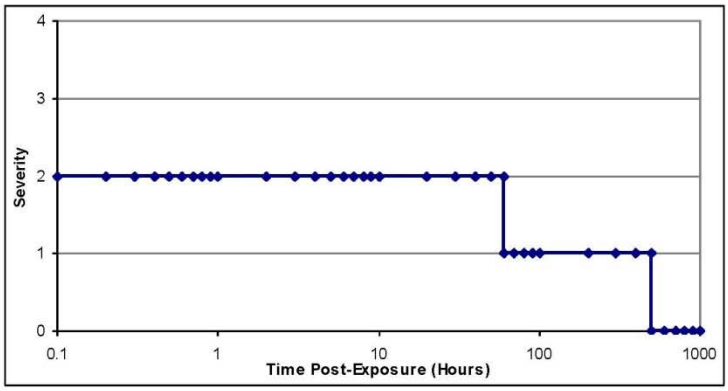


Note: This graphs differs from the one found in the Blast read-ahead

24 June 2008 24

Blast S/S Map for Insult Range of 240–290 kPa

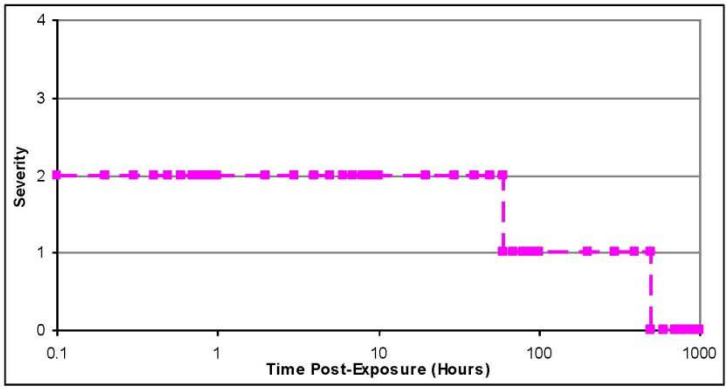
UPPER GI



24 June 2008 25

Blast S/S Map for Insult Range of 240–290 kPa

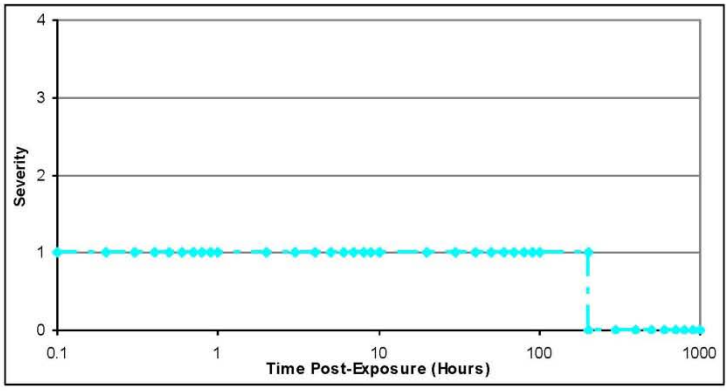
LOWER GI



24 June 2008 26

Blast S/S Map for Insult Range of 240–290 kPa

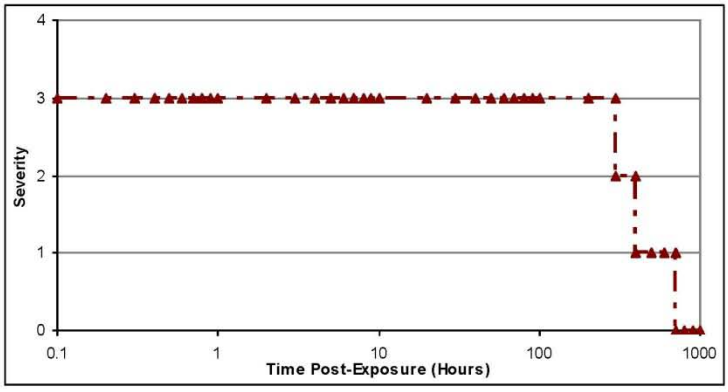
CARDIOVASCULAR



24 June 2008 27

Blast S/S Map for Insult Range of 240–290 kPa

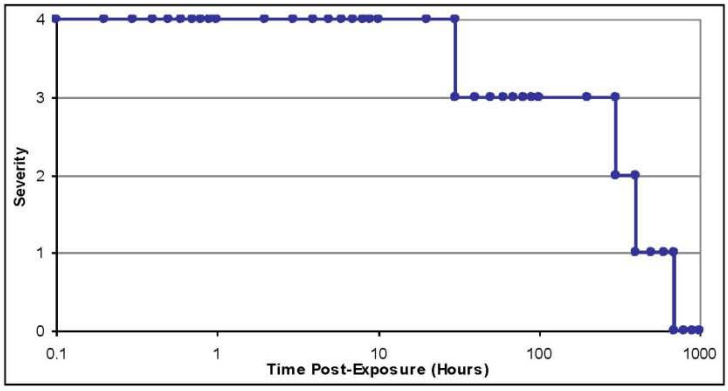
RESPIRATORY



Note: This graphs differs from the one found in the Blast read-ahead

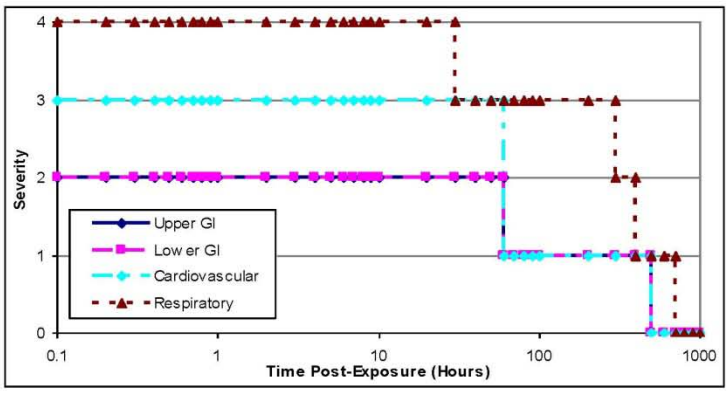
24 June 2008 28

Blast Injury Profile Map for Insult Range of > 290 kPa



24 June 2008 29

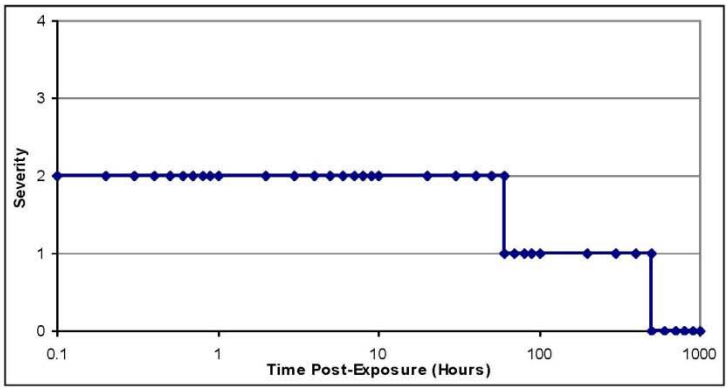
Blast Injury Progression Map for Insult Range of > 290 kPa



24 June 2008 30

Blast S/S Map for Insult Range of > 290 kPa

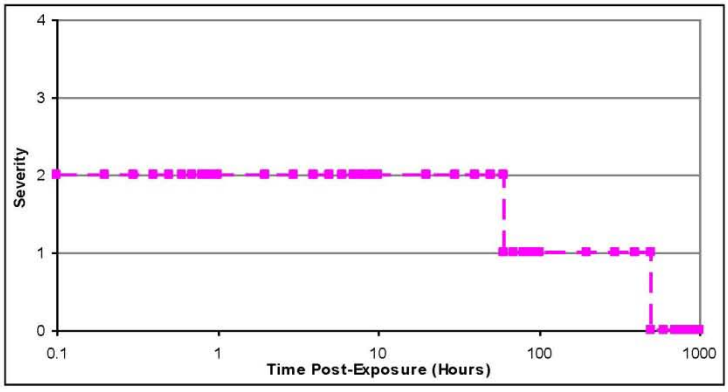
UPPER GI



24 June 2008 31

Blast S/S Map for Insult Range of > 290 kPa

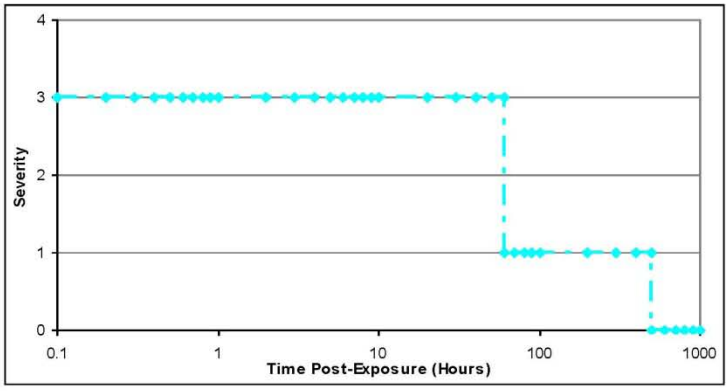
LOWER GI



24 June 2008 32

Blast S/S Map for Insult Range of > 290 kPa

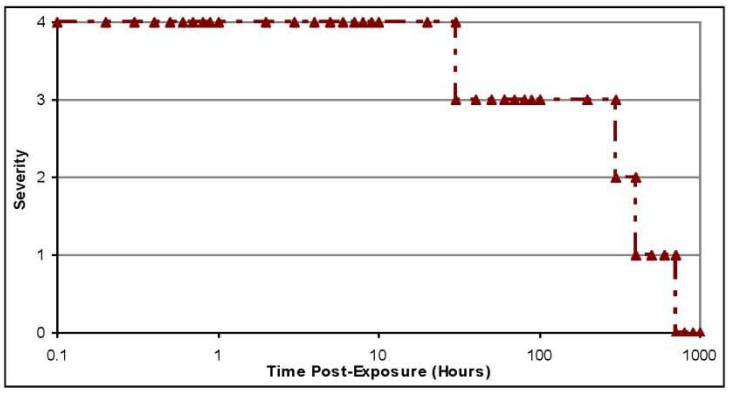
CARDIOVASCULAR



24 June 2008 33

Blast S/S Map for Insult Range of > 290 kPa

RESPIRATORY



24 June 2008 34

INJURIES DUE TO DYNAMIC PRESSURE EFFECTS

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Injuries Due to Dynamic Pressure Effects

- Dynamic pressure effects – such as secondary (missiling) or tertiary (whole body translation) – are not considered in the proposed methodology
  - Uncertainties in the environment
  - Uncertainties in terms of target posture
- As a result casualties and fatalities may be underestimated
- How should these effects be included?

Injuries Due to Dynamic Pressure Effects (cont'd)

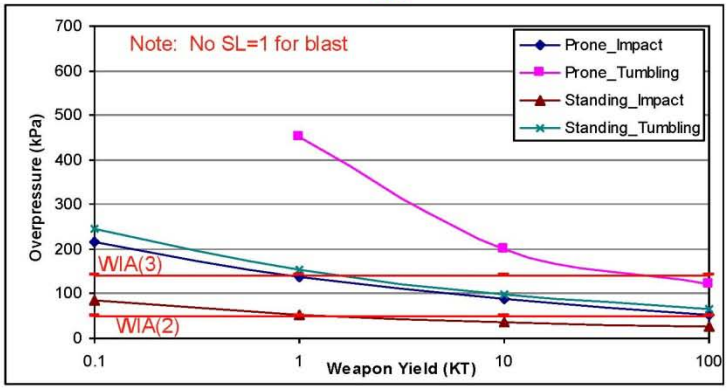
- Here is one possible approach
  - Based upon whole body translation and impact velocity for various effects
    - Impact velocity for BD_{50} = 4.7 m/s
    - Impact velocity for LD_{50} = 10.7 m/s
  - Impact velocity is very dependent upon yield
  - Consider four combinations of target posture and environment
    - Target prone (random orientation) impacting on "non-yielding" surface after traveling 3 meters
    - Target prone (random orientation) undergoing decelerative tumbling (open field)
    - Target standing either front- or back-on to wind impacting on "non-yielding" surface after traveling 3 meters
    - Target standing either front- or back-on to wind undergoing decelerative tumbling (open field)

Injuries Due to Dynamic Pressure Effects (cont'd)

- Here is one possible approach (cont'd)
  - Identify static overpressures associated with the dynamic overpressures required to achieve desired effect (median casualty or death – BD_{50} or LD_{50}) by yield
  - Given a yield and a posture-environment:
    - If static overpressure $\geq$ BD_{50} level, then immediate casualty (WIA)
    - If static overpressure > LD_{50} level, then immediate fatality (KIA)

Overpressures Required to Achieve Injury Due to Translation Effects

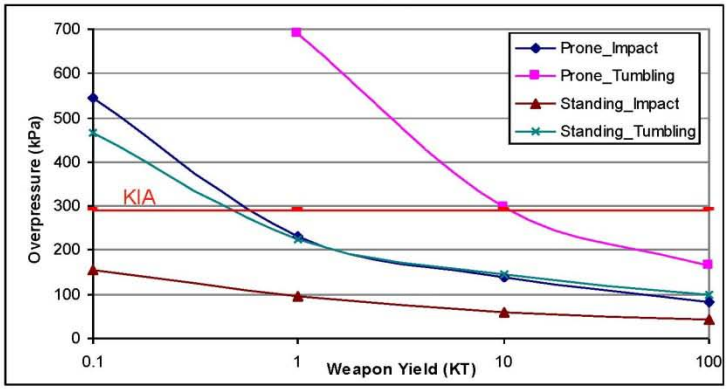
BD_{50}



Derived from Drake, et. al. *An Interim Report on Collateral Damage*, DNA 4734Z, Science Applications, Inc. for the Defense Nuclear Agency, 1978, p. 5-94

Overpressures Required to Achieve Death Due to Translation Effects

LD_{50}



Derived from Drake, et. al. *An Interim Report on Collateral Damage*, DNA 4734Z, Science Applications, Inc. for the Defense Nuclear Agency, 1978, p. 5-94

Injuries Due to Dynamic Pressure Effects: Issues

- Should the human response methodology include dynamic pressure effects?
- Should this methodology include
  - Single posture (standing vs prone)
  - Single posture-environment (standing--tumbling)
  - Only fatalities as a function of dynamic pressure
  - All charts and tables
- Are there other approaches?

Questions?

Contact

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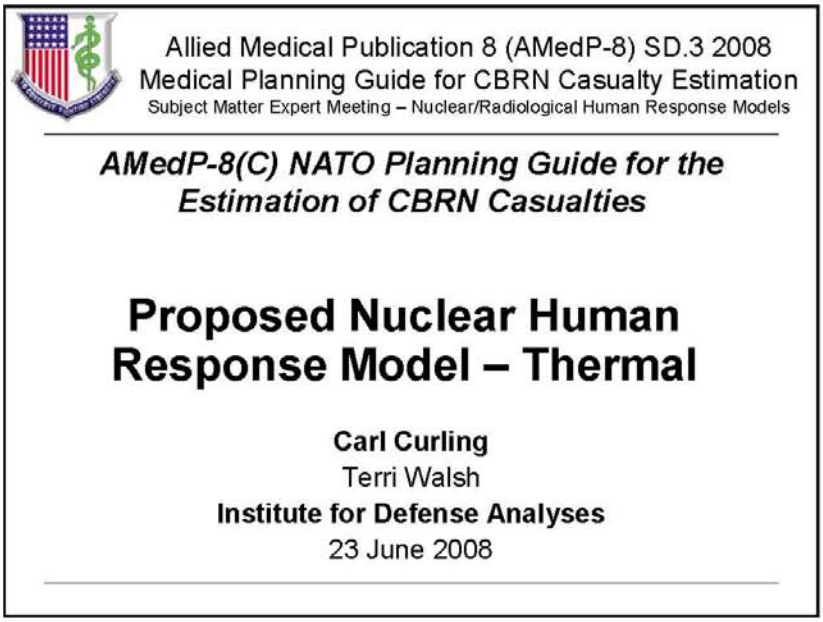
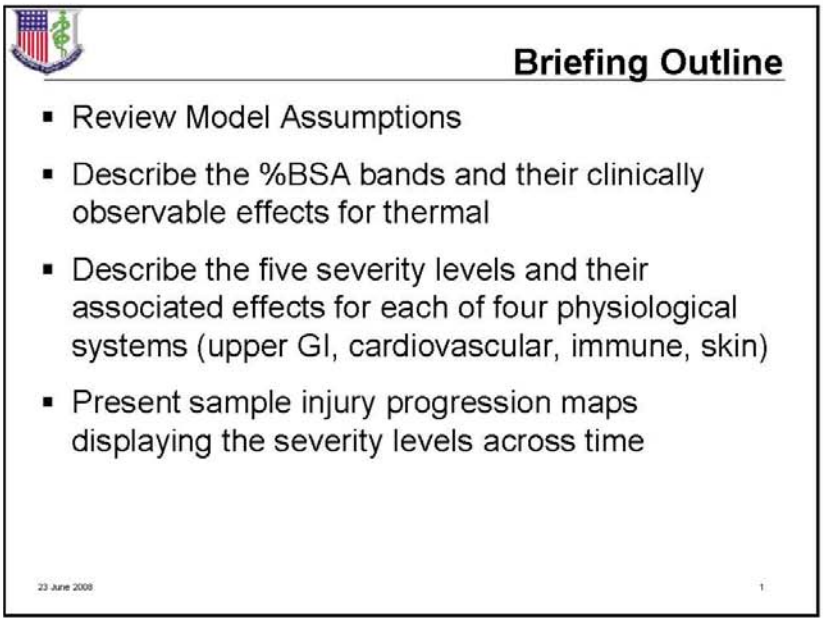
ddisrael@ida.org 703-845-6685

H. Proposed Nuclear Human Response Model – Thermal – *Briefing*





MODEL ASSUMPTIONS

Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related effects (signs and symptoms)
  - Dose-related effects apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health.
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- Human response is modeled as primary response to prompt, instantaneous insults
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted
  - Human response for the entire exposed population begins simultaneously immediately following the nuclear detonation

Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization
- Thermal assumptions:
  - The methodology does not account for thermal burns to the face, hands, feet, or genitalia differently from burns to other parts of the body
  - The thermal energy associated with the nuclear environment can be translated to a percentage body surface area burned, depending on uniform or clothing worn and garment fit
  - %BSA is the percent area of skin with 2nd degree burns and may include 3rd degree burns

THERMAL %BSA BANDS

Thermal Insult Range

Thermal Insult Range (%BSA)	Description*
< 1%	No observable effect**
1 – 10%	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
11 – 20%	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
21 – 30%	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain
31 – 40%	10% fatalities; increased upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; decreased blood pressure (possibility of shock); initial increase in pain followed by a decrease in pain; compromise of the immune system
≥ 41%	50% fatalities; upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia

* Estimation of burn lethality is approximate
** <1%BSA may include a larger area of 1st degree burns

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Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

THERMAL SEVERITY LEVELS AND SIGNS / SYMPTOMS

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Severity Definitions

	Degrees	Description
0	N.O.E.	No observable effect
1	Mild	Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms
2	Moderate	Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission
3	Severe	Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms
4	Very Severe	Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms

Signs / Symptoms Systems

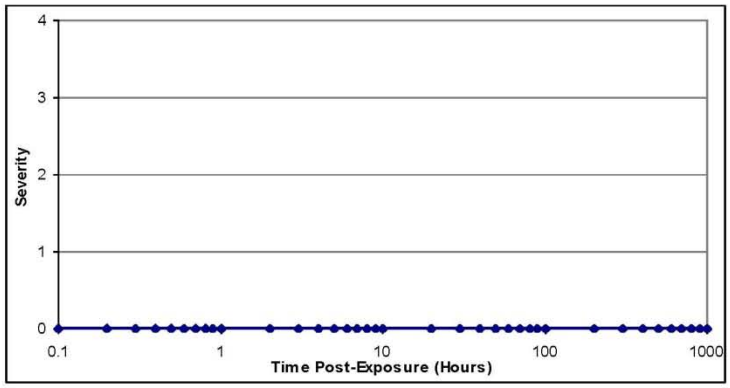
	Irradiation	Blast	Thermal
Cardiovascular	X	X	X
Immune	X		X
Lower Gastrointestinal	X	X	
Respiratory		X	
Skin (Thermal)			X
Upper Gastrointestinal	X	X	X

Sign/Symptoms Severities

Signs / Symptoms Severity	Upper GI Signs/Symptoms	Cardiovascular Signs/Symptoms
0	No observable effect	No observable effect
1	Upset stomach and nausea; watering mouth and frequent swallowing to avoid vomiting	Slight feeling of light headedness
2	Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting	Unsteadiness upon standing quickly
3	Protracted or continued vomiting, including dry heaves	Severe dizziness; faints upon standing quickly; may have difficulty stopping any bleeding
4		Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain

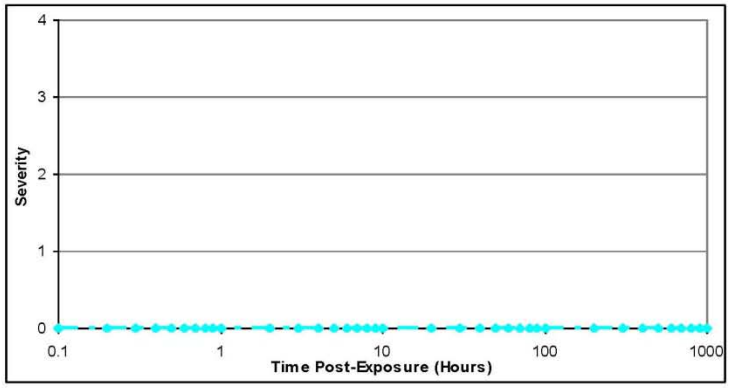
Thermal S/S Map for Insult Range of 1–10%BSA

UPPER GI



Thermal S/S Map for Insult Range of 1–10%BSA

CARDIOVASCULAR

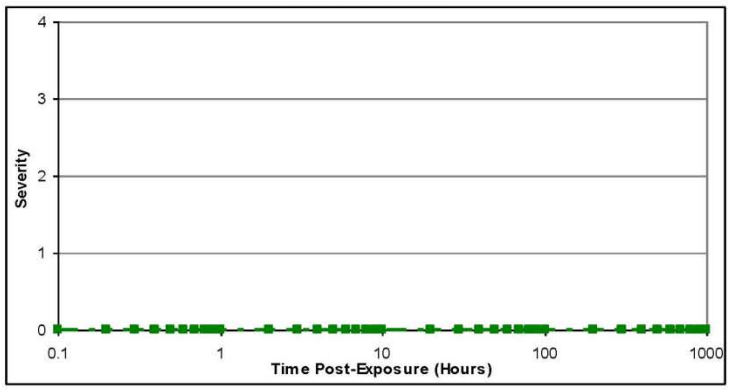


Signs / Symptoms Systems

Signs / Symptoms Severity	Immune Signs/Symptoms	Skin (Thermal) Signs/Symptoms
0	No observable effect	No observable effect
1	Slight fever and headache	Partial thickness (2nd degree) and epidermal burns (1st degree) over small body surface area characterized by skin redness, swelling, and blistering; persistent pain at burn site
2	Aching joints; fever; lack of appetite; sores in mouth/throat	Partial thickness burns (2nd degree) over larger body surface area combined with some full thickness burns (3rd degree); pain at sites of partial thickness burns; potential for fluid loss through burn sites
3	High fever results in shakes, chills and aches all over	Partial (2nd degree) and full thickness (3rd degree) burns over up to 50% of the body surface area; limited pain due to nerve damage from 3rd degree burns; significant fluid loss through burn sites
4	Delirium from fever; overwhelming infections	>50% BSA with partial (2nd degree) and full thickness (3rd degree) burns

Thermal S/S Map for Insult Range of 1–10%BSA

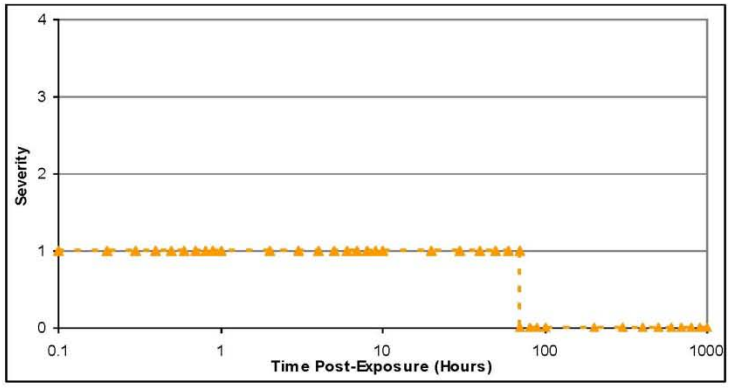
IMMUNE



23 June 2008 14

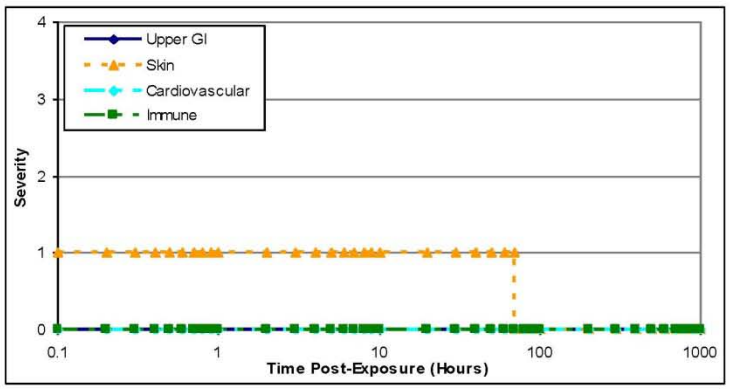
Thermal S/S Map for Insult Range of 1–10%BSA

SKIN



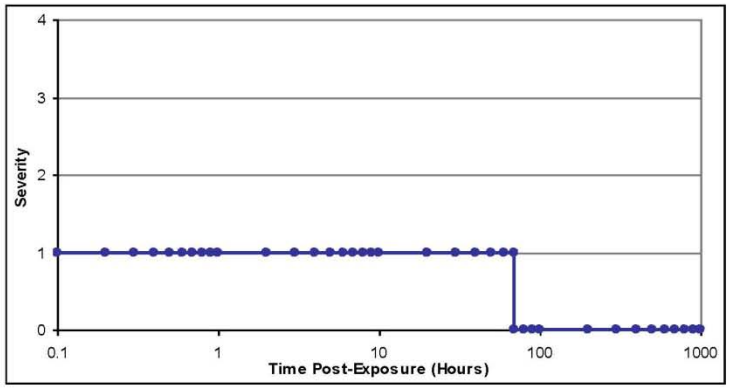
23 June 2008 15

Thermal Injury Progression Map for Insult Range of 1–10%BSA



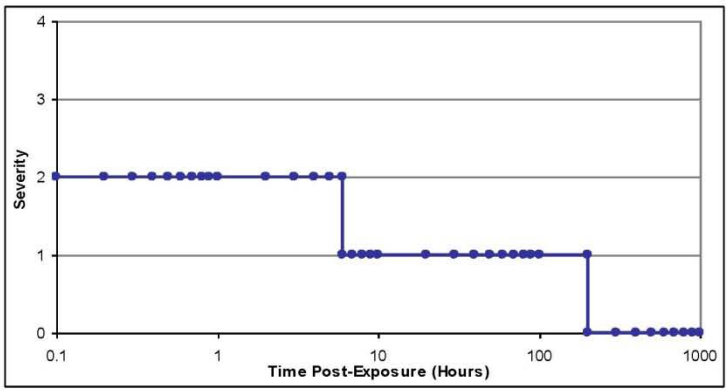
23 June 2008 16

Thermal Injury Profile Map for Insult Range of 1–10%BSA



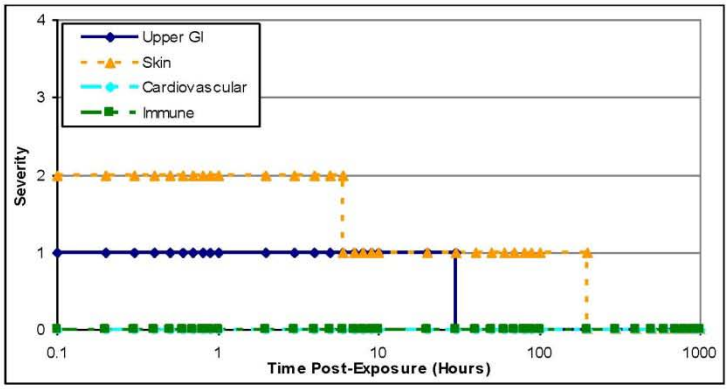
23 June 2008 17

Thermal Injury Profile Map for Insult Range of 11–20%BSA



23 June 2008 18

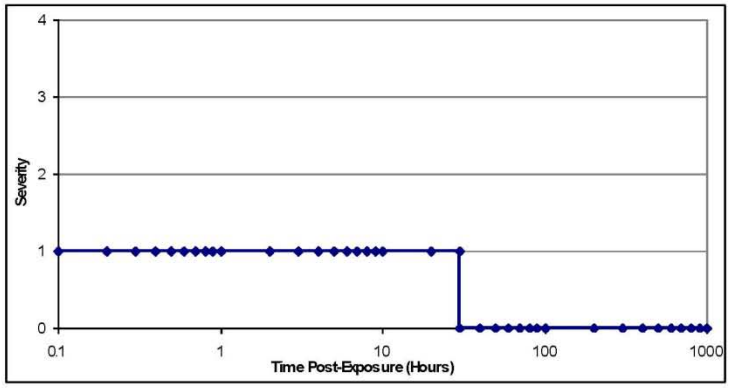
Thermal Injury Progression Map for Insult Range of 11–20%BSA



23 June 2008 19

Thermal S/S Map for Insult Range of 11–20%BSA

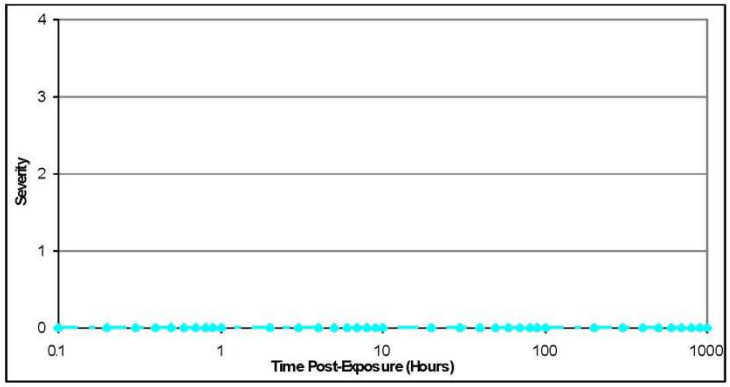
UPPER GI



23 June 2008 20

Thermal S/S Map for Insult Range of 11–20%BSA

CARDIOVASCULAR



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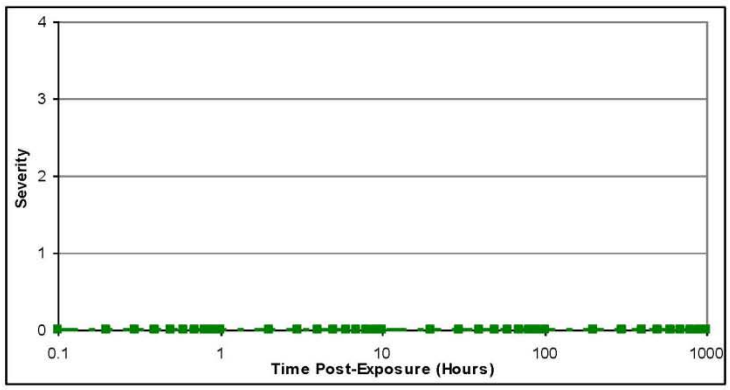
Thermal S/S Map for Insult Range of 11–20%BSA

IMMUNE



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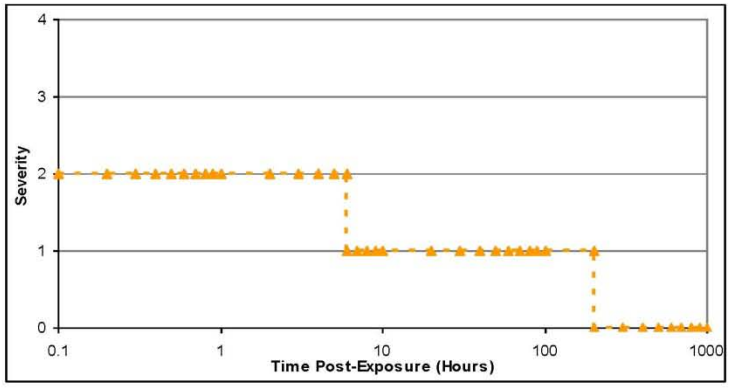
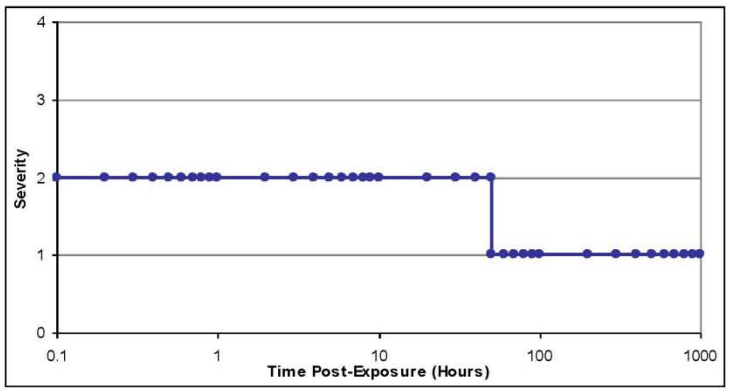
Thermal S/S Map for Insult Range of 11–20%BSA

SKIN



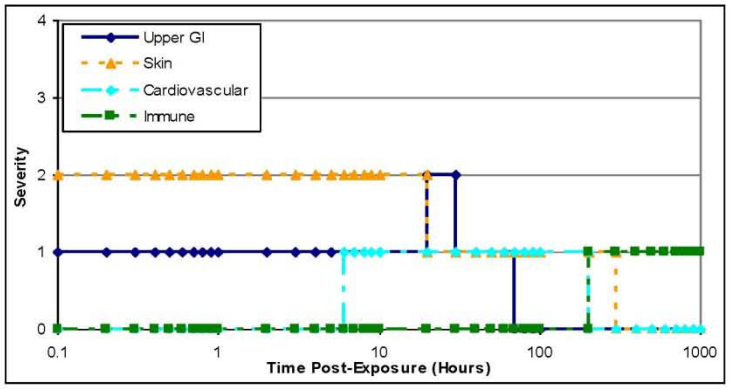
23 June 2008 23

Thermal Injury Profile Map for Insult Range of 21–30%BSA



23 June 2008 24

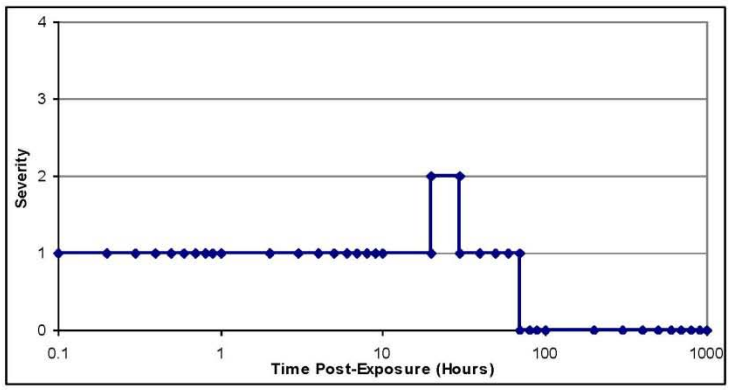
Thermal Injury Progression Map for Insult Range of 21–30%BSA



23 June 2008 25

Thermal S/S Map for Insult Range of 21–30%BSA

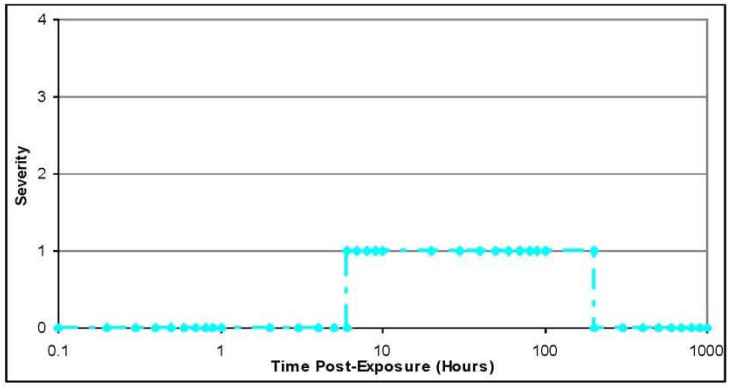
UPPER GI



23 June 2008 26

Thermal S/S Map for Insult Range of 21–30%BSA

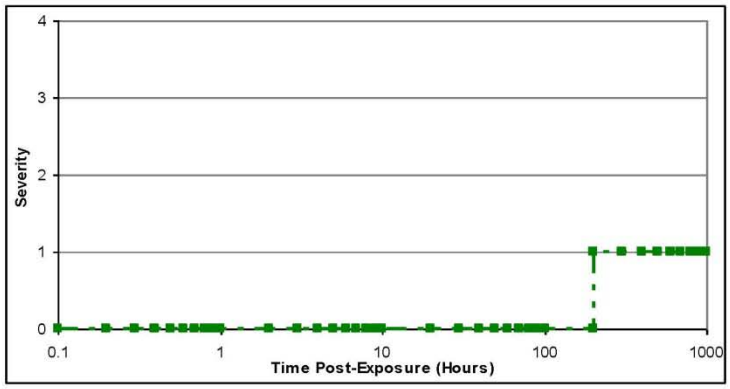
CARDIOVASCULAR



23 June 2008 27

Thermal S/S Map for Insult Range of 21–30%BSA

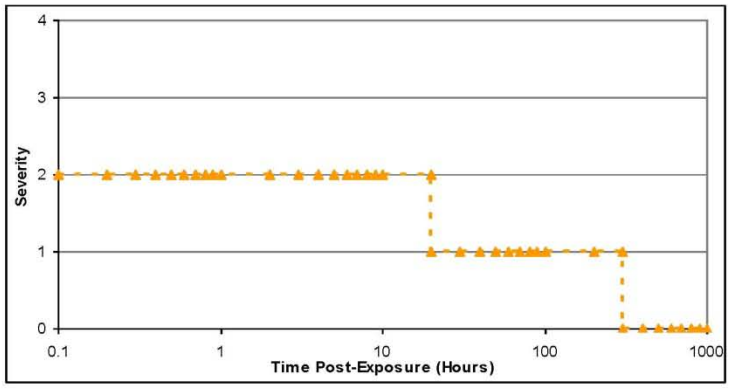
IMMUNE



23 June 2008 28

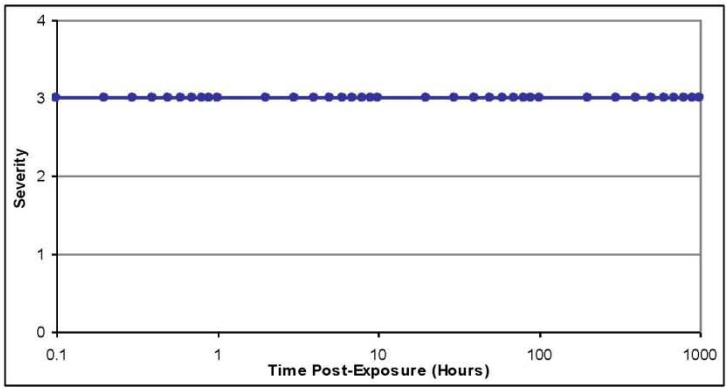
Thermal S/S Map for Insult Range of 21–30%BSA

SKIN



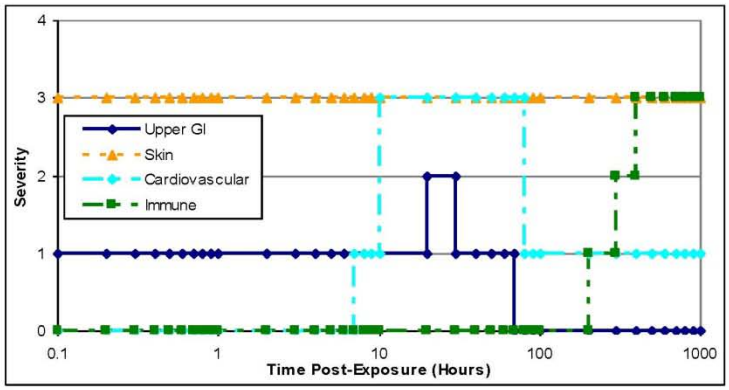
23 June 2008 29

Thermal Injury Profile Map for Insult Range of 31–40%BSA



23 June 2008 30

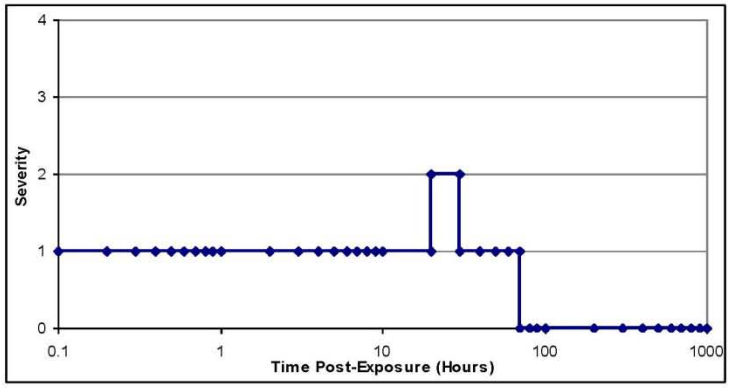
Thermal Injury Progression Map for Insult Range of 31–40%BSA



23 June 2008 31

Thermal S/S Map for Insult Range of 31–40%BSA

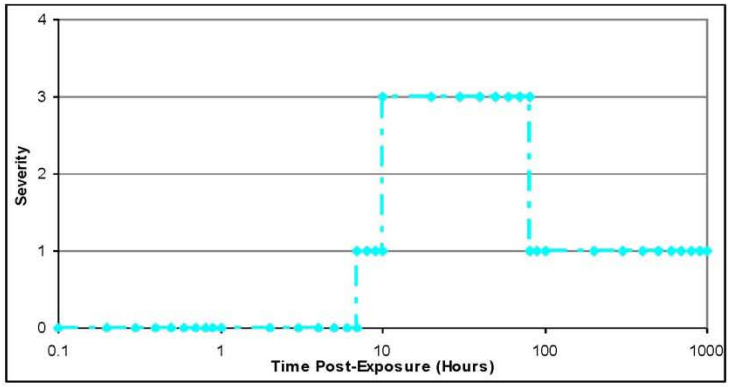
UPPER GI



23 June 2008 32

Thermal S/S Map for Insult Range of 31–40%BSA

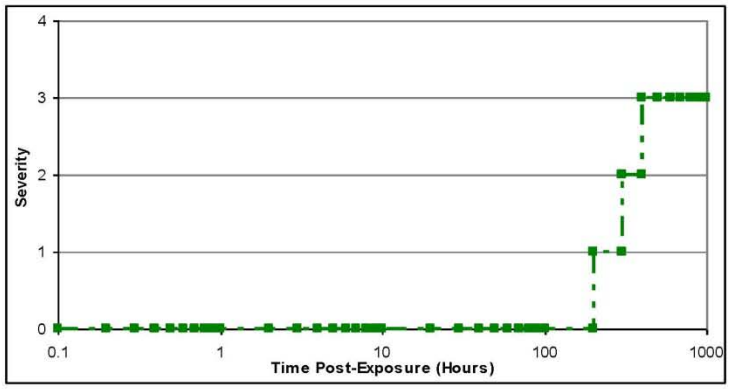
CARDIOVASCULAR



23 June 2008 33

Thermal S/S Map for Insult Range of 31–40%BSA

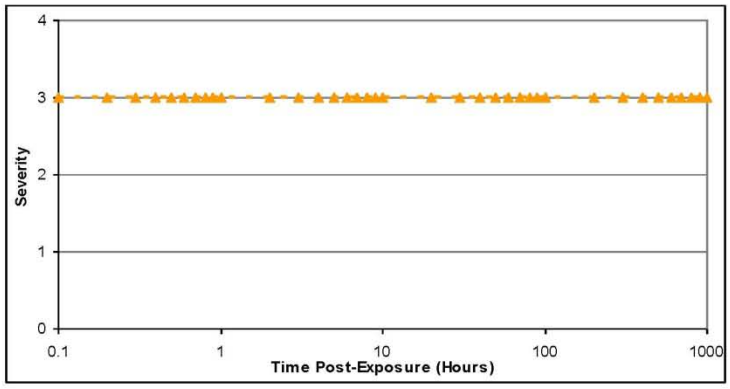
IMMUNE



23 June 2008 34

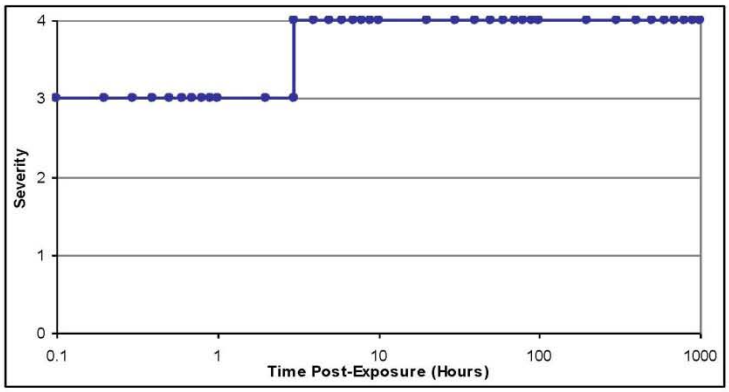
Thermal S/S Map for Insult Range of 31–40%BSA

SKIN



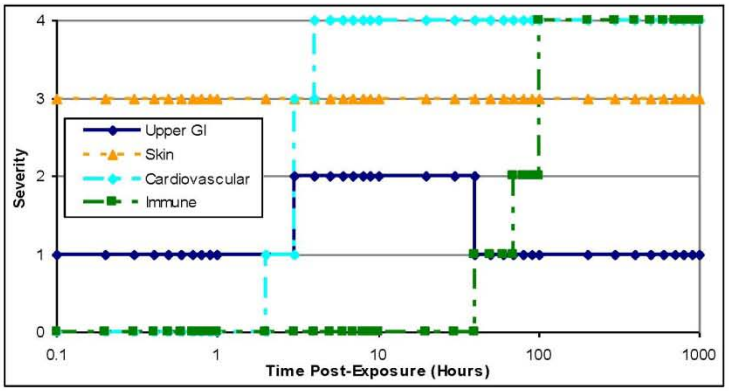
23 June 2008 35

Thermal Injury Profile Map for Insult Range of ≥ 41%BSA



23 June 2008 36

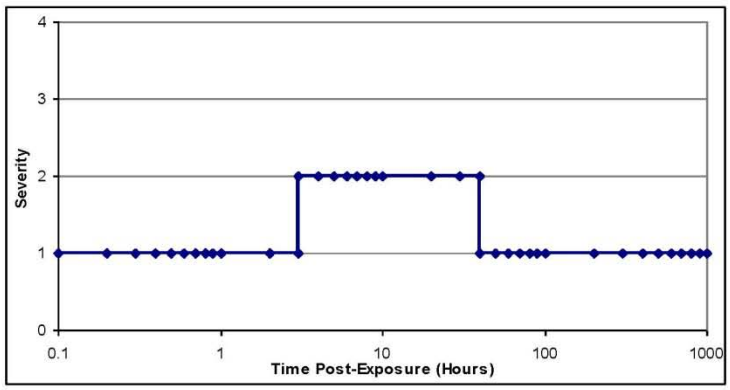
Thermal Injury Progression Map for Insult Range of ≥ 41%BSA



23 June 2008 37

Thermal S/S Map for Insult Range of ≥ 41%BSA

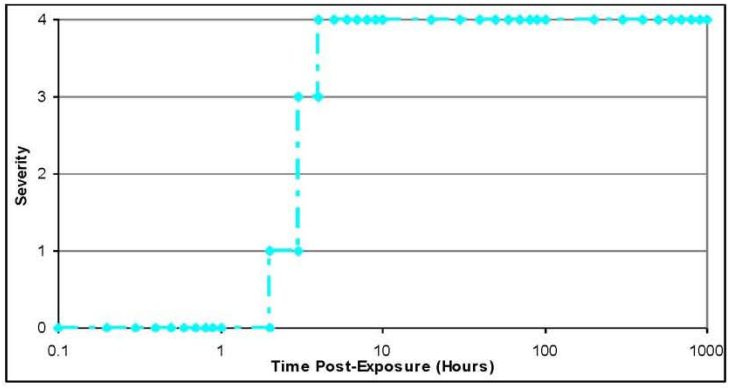
UPPER GI



23 June 2008 38

Thermal S/S Map for Insult Range of ≥ 41%BSA

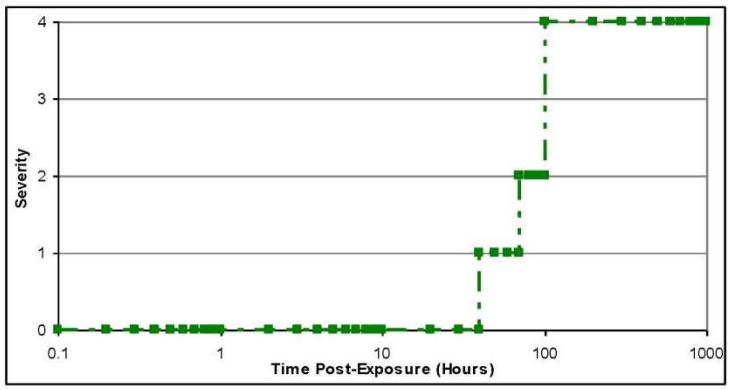
CARDIOVASCULAR



23 June 2008 39

Thermal S/S Map for Insult Range of ≥ 41%BSA

IMMUNE



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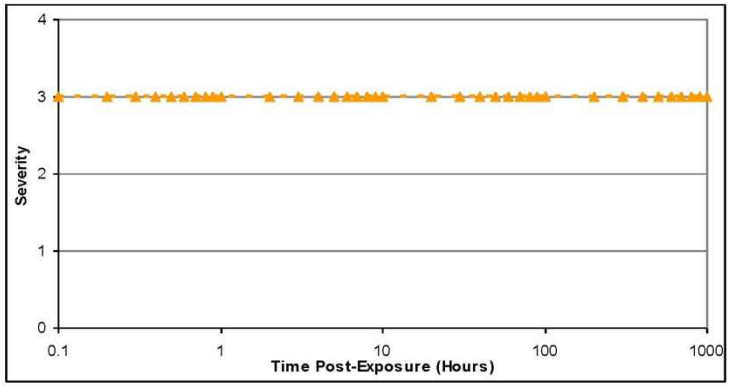
Thermal S/S Map for Insult Range of ≥ 41%BSA

SKIN



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Questions?

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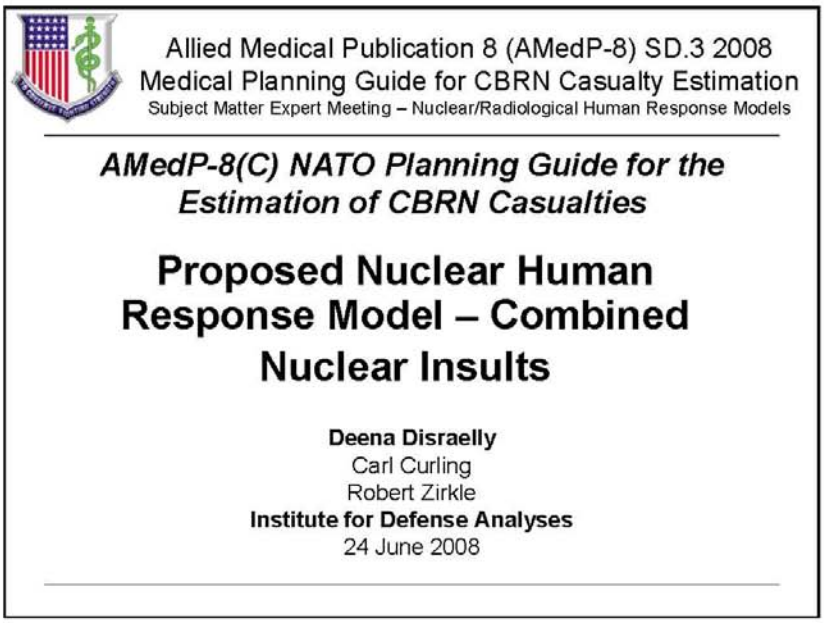
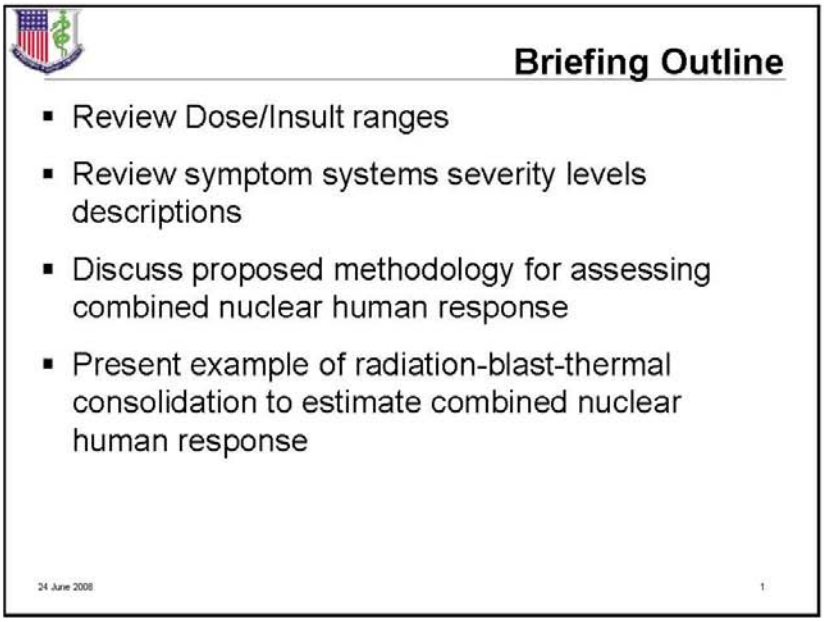
rzirkle@ida.org 703-845-2038

I. Proposed Nuclear Human Response Model – Combined Nuclear Insults – *Briefing*





R-B-T DOSE BANDS

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Radiation Dose Range

Dose Range (Gy)	Description
0 – 1.25	No observable effect
1.25 – 3	A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is >90 percent unless there are other injuries
3 – 5.3	Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible lethality
5.3 – 8.3	Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries they may die within 2 weeks
> 8.3	Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2-3 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1-2.5 weeks or if other injuries are also present, patients may die within 6 days

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Derived from NATO. *AMedP-8. Op. cit.* p. 3-9; and, NATO. *STANAG 2083.*

Blast Insult Range

Exp. Range (kPa)	Description
< 50	No observable effect
50 – 140	50% eardrum rupture; threshold lung damage; threshold gastrointestinal damage
140 – 240	50% burdening level (BD_{50}) lung damage; 90% burdening level (BD_{90}) tympanic membrane rupture
240 – 290	90% burdening level (BD_{90}) lung damage; 10% fatalities (LD_{10})
> 290	50% fatalities (LD_{50})

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Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

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Thermal Insult Range

Thermal Insult Range (% BSA)	Description*
< 1%	No observable effect**
1 – 10%	1st, 2nd and possible 3rd degree burns; electrolyte imbalance; pain
11 – 20%	Upper GI discomfort; 1st, 2nd and possible 3rd degree burns; electrolyte imbalance; increased pain
21 – 30%	10% fatalities; upper GI discomfort; 1st, 2nd and possible 3rd degree burns; fluid loss; decreased renal blood flow; compromise of the immune system; pain
≥ 31%	≥ 50% fatalities; upper GI discomfort; 2nd and 3rd degree burns; hypovolemia; decreased renal blood flow; shock resulting from blood pressure decrease; cardiac distress; toxemia; multiple organ failure

* Estimation of burn lethality is approximate

** <1%BSA may include a larger area of 1st degree burns

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Derived from NATO. *AMedP-8. Op. cit.* p. 3-9.

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INJURY SEVERITY LEVELS

Severity Definitions

	Degrees	Description
0	N.O.E.	No observable effect
1	Mild	Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms
2	Moderate	Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission
3	Severe	Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms
4	Very Severe	Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms

Symptoms Severities

Signs / Symptoms Severity	Upper GI Symptoms	Lower GI Symptoms
0	No observable effect	No observable effect
1	Upset stomach and nausea; watering mouth and frequent swallowing to avoid vomiting	Abdominal pain or cramps; occasional diarrhea and uncomfortable urge to defecate
2	Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting	Frequent diarrhea and cramps; continuing defecation
3	Protracted or continued vomiting, including dry heaves	Uncontrollable diarrhea and urination; painful cramps
4	Rigid belly and extreme abdominal pain+	

+ Upper gastrointestinal signs and symptoms at severity level 4—Very Severe—apply only to blast-induced injuries

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Symptoms Systems

Signs / Symptoms Severity	Cardiovascular Symptoms	Immune Symptoms
0	No observable effect	No observable effect
1	Slightly feeling of light headedness	
2	Unsteadiness upon standing quickly; possible micro-hemorrhaging	Increased rate of infection; aching joints; fever; sores in mouth/throat; possible skin lesions
3	Severe dizziness; faints upon standing quickly; possible difficulty stopping any bleeding	High fever results in shakes, chills and aches all over
4	Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain	Delirium from fever; overwhelming infections

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Symptoms Systems

Signs / Symptoms Severity	Respiratory Symptoms
0	No observable effect
1	Mild shortness of breath
2	Frank shortness of breath, respiratory congestion, non-productive cough
3	Air hunger; labored breathing; breathing sporadically stops and starts; hemoptysis (spits up blood)
4	Breathing stops completely or struggling to breathe; cyanosis (skin has a purple or blue color); prostration

Symptoms Systems

Signs / Symptoms Severity	Skin (Thermal) Symptoms
0	No observable effect
1	Epidermal burns (1st degree) over small body surface area characterized by skin redness, swelling, and blistering; persistent pain at burn site
2	Partial thickness burns (2nd degree) over larger body surface area combined with some full thickness burns (3rd degree); pain at sites of partial thickness burns; potential for fluid loss through burn sites
3	Partial (2nd degree) and full thickness (3rd degree) burns over up to 30% of the body surface area; limited pain due to nerve damage from 3rd degree burns; significant fluid loss through burn sites
4	>30% BSA with partial (2nd degree) and full thickness (3rd degree) burns

PROPOSED COMBINED METHODOLOGY

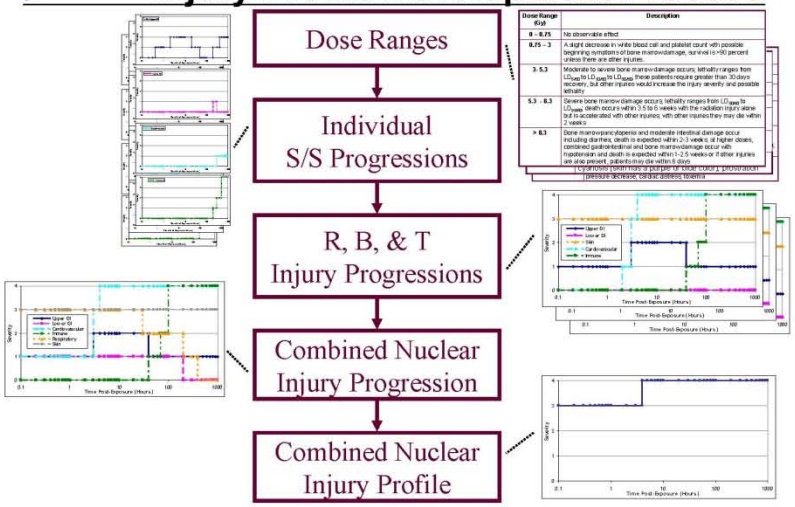
Symptoms Systems

	Irradiation	Blast	Thermal
Cardiovascular	X	?	X
Immune	X		X
Lower Gastrointestinal	X	?	
Respiratory		X	
Skin (Thermal)			X
Upper Gastrointestinal	X	?	?

Specific Model Assumptions

- Blast assumption:
  - Injuries due to dynamic pressure effects are not included
- Thermal assumptions:
  - The methodology does not account for thermal burns to the face, hands, feet, or genitalia differently from burns to other parts of the body
  - The thermal energy associated with the nuclear environment can be translated to a percentage body surface area burned, depending on uniform or clothing worn and garment fit
  - %BSA is the percent area of skin with 2nd degree burns and may include 3rd degree burns
- Combined assumptions:
  - Severity of signs and symptoms resulting from combined insults is interactive

Injury Profile Development Process



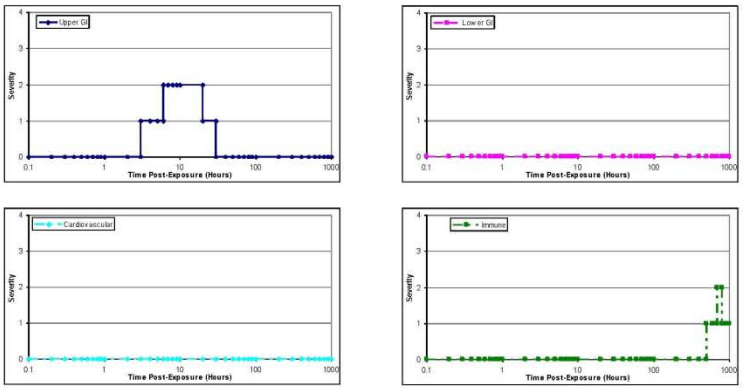
EXAMPLE: COMBINED NUCLEAR HUMAN RESPONSE

Example Case: Nuclear

- Nuclear Example Case Exposures
  - Radiation: 4 Gy
  - Blast: 200 kPa
  - Thermal: 25%BSA

Example Case: Nuclear

- Radiation: 4 Gy



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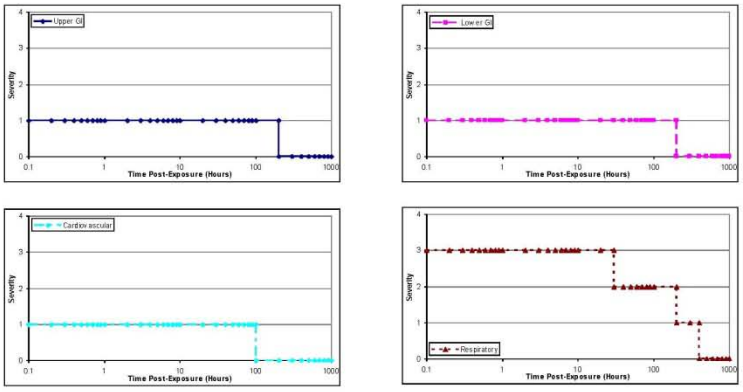
Example Case: Nuclear

- Blast: 200 kPa



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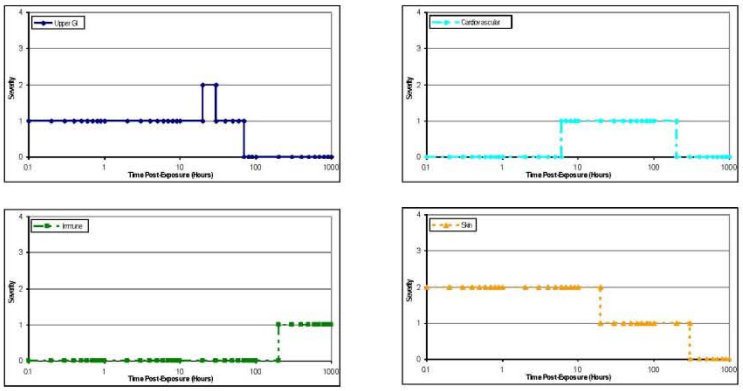
Example Case: Nuclear

- Thermal: 25%BSA



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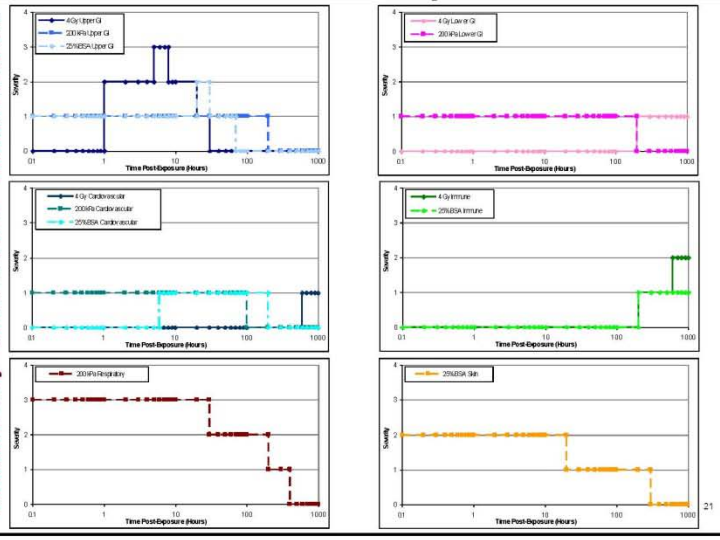
Example Case: Nuclear

Radiation: 4 Gy—Blast: 200 kPa—Thermal: 25%BSA



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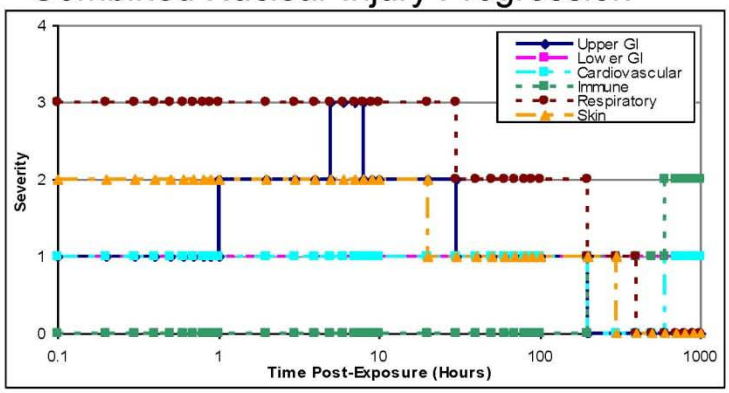
Example Case: Nuclear

- Combined Nuclear Injury Progression



Radiation: 4 Gy—Blast: 200 kPa—Thermal: 25%BSA

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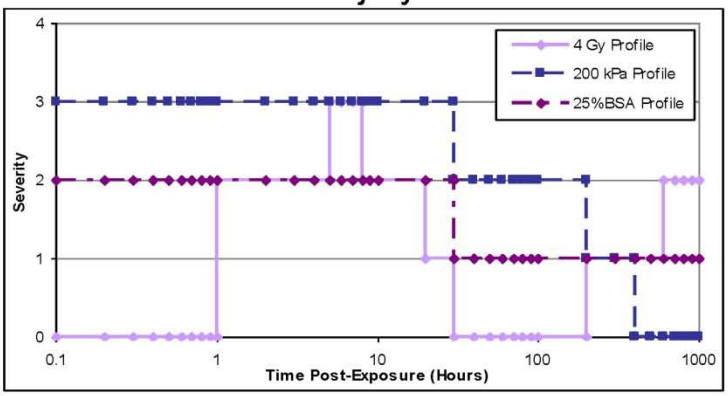
Example Case: Nuclear

- Individual Nuclear Injury Profiles



Radiation: 4 Gy—Blast: 200 kPa—Thermal: 25%BSA

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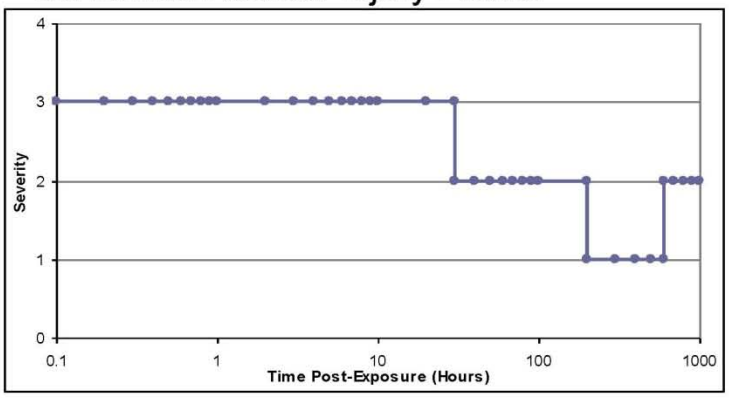
Example Case: Nuclear

- Combined Nuclear Injury Profile



Radiation: 4 Gy—Blast: 200 kPa—Thermal: 25%BSA

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Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

Questions?

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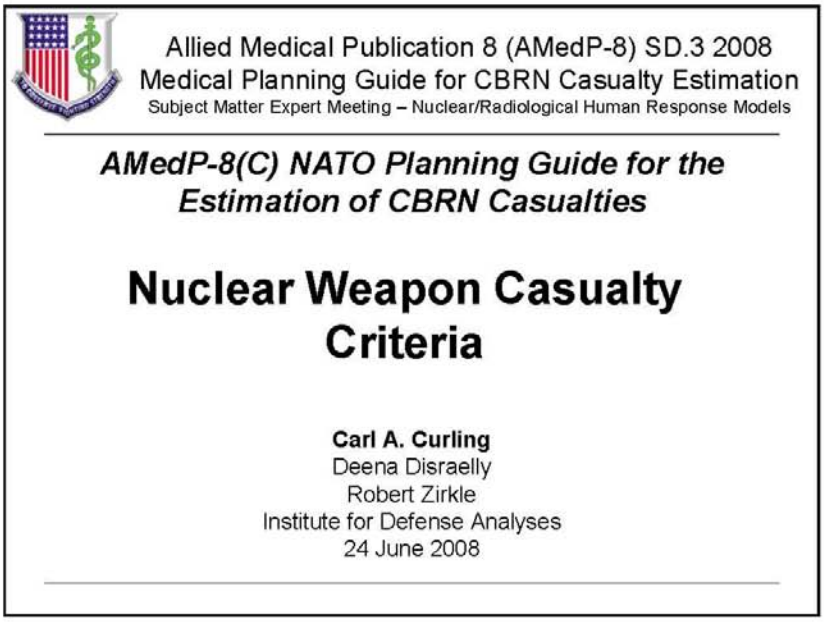
703-578-2814	703-845-6685	703-845-2038

J. Nuclear Weapon Casualty Criteria – *Briefing*

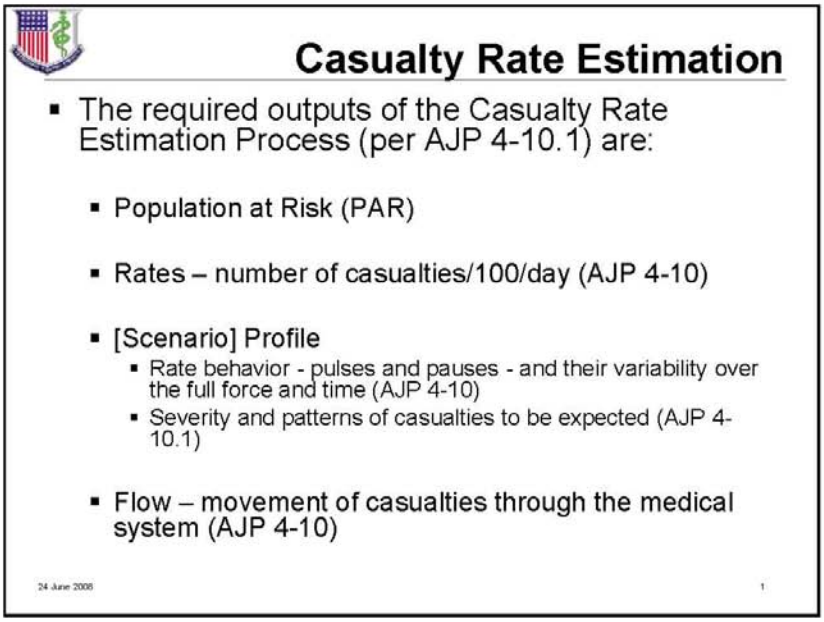


Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties

Nuclear Weapon Casualty Criteria

Carl A. Curling
Deena Disraelly
Robert Zirkle
Institute for Defense Analyses
24 June 2008



Casualty Rate Estimation

- The required outputs of the Casualty Rate Estimation Process (per AJP 4-10.1) are:
  - Population at Risk (PAR)
  - Rates – number of casualties/100/day (AJP 4-10)
  - [Scenario] Profile
    - Rate behavior - pulses and pauses - and their variability over the full force and time (AJP 4-10)
    - Severity and patterns of casualties to be expected (AJP 4-10.1)
  - Flow – movement of casualties through the medical system (AJP 4-10)

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AMedP-8 Human Response Models

The proposed Human Response Models:

- Estimates the personnel status over time after exposure to some Chemical, Biological, Radiological, or Nuclear agent or effect
- Allow for estimation of:
  - KIA as a function of specific levels of effect
  - WIA at the time at which signs, symptoms and/or injury reach a specified severity level or as a function of specific effect levels
  - DOW at some time after agent or effect exposure as a function of an agent/effect-related estimation or a specified severity level
- Also allow for a description of effects or "injury" severities over time

CASUALTY RATE ESTIMATOR OUTPUT CHARACTERIZATION

[Scenario] Profile

A. Casualty Type
- KIA, WIA, DOW

Amplifying WIA Information:

B. Injury or Disease Severity
- Mild, Moderate, Severe, Very Severe at organism level

C. Injury or Disease Severity by Effect
- **Mild, Moderate, Severe, Very Severe for each of Radiation, Blast and Thermal at organism level**

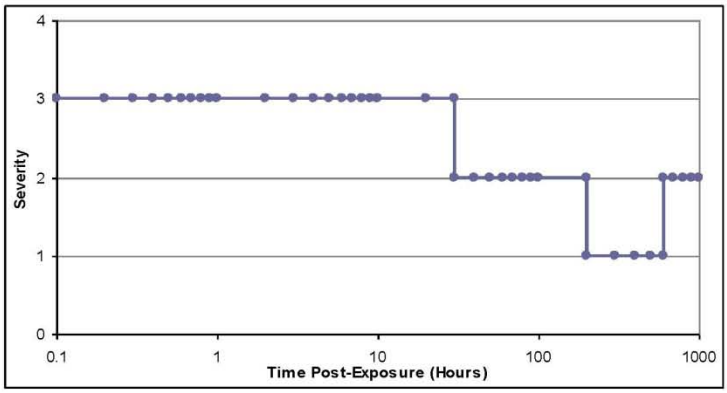
D. System
- Cardiovascular, Immune, Lower GI, Respiratory, Skin (Thermal), Upper GI

E. System Severity
- Mild, Moderate, Severe, Very Severe for each of:
  - Cardiovascular, Immune, Lower GI, Skin (Thermal), Respiratory, Upper GI

F. Sign / Symptom Description
- Vomiting, difficulty breathing, partial thickness (2nd degree) and epidermal burns (1st degree), …

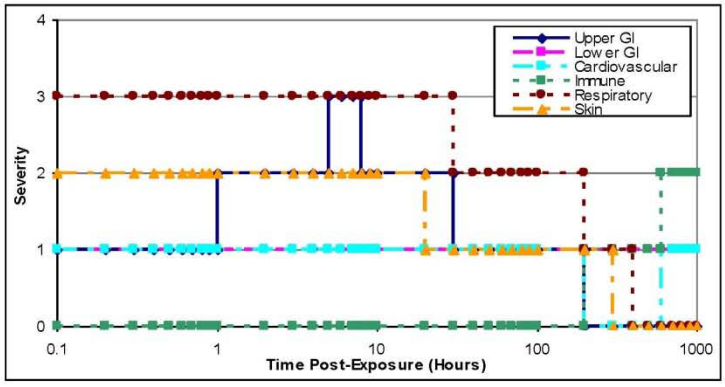
Illustrative Example

Nuclear exposure of 4 Gy, 200 kPa, 25%BSA



Illustrative Example

Nuclear exposure of 4 Gy, 200 kPa, 25%BSA



Illustrative Example [Scenario] Profile

A. Casualty Type
- WIA

B. Injury or Disease Severity
- Severe nuclear WIA

C. Injury or Disease Severity by Effect
- **WIA with mild radiation and moderate burn injuries, and severe blast injuries**

D. System
- Upper GI, Lower GI, Cardiovascular, Respiratory, Skin (Thermal),

Illustrative Example [Scenario] Profile

E. System Severity
- Immediately Post Exposure:
  - WIA with severe respiratory, moderate skin and mild upper and lower GI and cardiovascular signs and symptoms
- 6 hours Post Exposure:
  - WIA with severe respiratory and upper GI, moderate skin, and mild lower GI and cardiovascular signs and symptoms
- 30 hour Post Exposure:
  - WIA with moderate respiratory and mild skin, upper and lower GI and cardiovascular signs and symptoms

Illustrative Example [Scenario] Profile

F. Sign / Symptom Description
- Immediately Post Exposure:
  - Hungry for air; labored breathing; breathing sporadically stops and starts; hemoptysis
  - Partial thickness burns (2^{nd} degree) over larger body surface area combined with some full thickness burns (3^{rd} degree); pain at sites of partial thickness burns; potential for fluid loss through burn sites
  - Upset stomach and nausea: watering mouth and frequent swallowing to avoid vomiting
  - Abdominal pain or cramps; occasional diarrhea and uncomfortable urge to defecate
  - Slight feeling of light headedness

Recommendation

[Scenario] Profile: The description of CBRN casualties by type, and for WIA; severity and disease or injury type (e.g. KIA, Nuc WIA with moderate radiation and blast injury, and severe burns, Nuc WIA with mild radiation injuries and no observable burn or blast injuries…)

Provides information on personnel status for the operational planner and injury types for the medical planner

- Time personnel are lost to unit
- Type of injury and implied medical requirement

RECOMMENDED VALUES

Recommended Casualty Definitions

AAP-6 Definitions:

- WIA - "In relation to personnel, any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured or missing."
- DOW - "A battle casualty who dies of wounds or other injuries received in action, after having reached a medical treatment facility."
- KIA - "A battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility."

Model Implementation:

- WIA - Individual whose injury profile severity ≥ 1
- DOW - Individual whose burn or blast injury profile severity = 4 for 15 minutes or 2 consecutive reporting times, or whose time to death from radiation injury is exceeded (whichever is earlier)
- KIA - Individual who meets the criteria for DOW before reaching a medical treatment facility (appr. 30 minutes post-detonation)

Questions?

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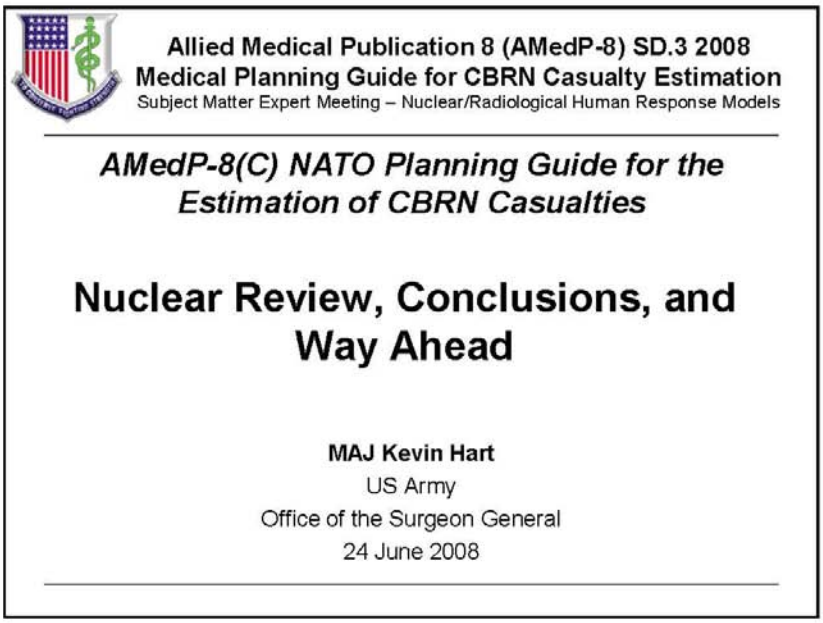
ccurling@ida.org ddisrael@ida.org rzirkle@ida.org
703-578-2814 703-845-6685 703-845-2038

K. Nuclear Review, Conclusions, and Way Ahead – *Briefing*



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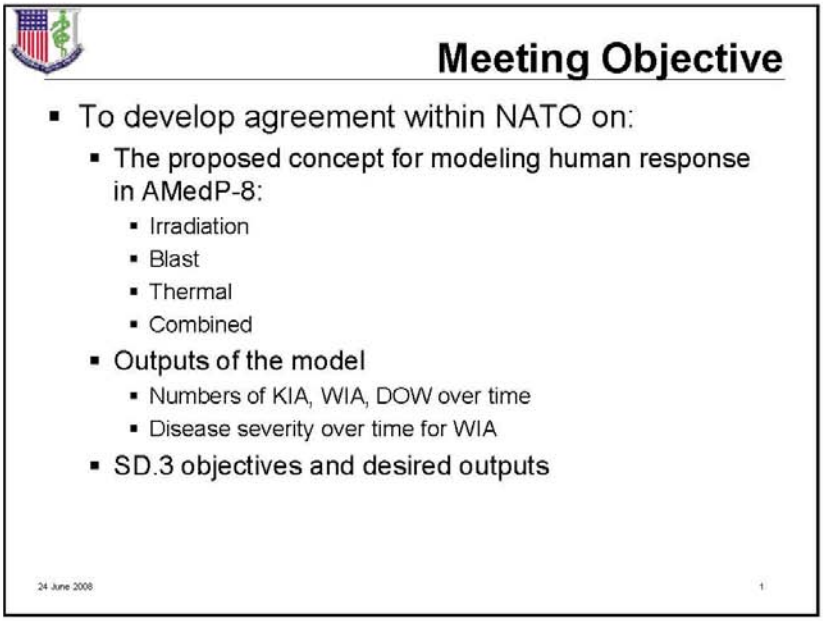
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties

Nuclear Review, Conclusions, and Way Ahead

MAJ Kevin Hart
US Army
Office of the Surgeon General
24 June 2008



Meeting Objective

- To develop agreement within NATO on:
  - The proposed concept for modeling human response in AMedP-8:
    - Irradiation
    - Blast
    - Thermal
    - Combined
  - Outputs of the model
    - Numbers of KIA, WIA, DOW over time
    - Disease severity over time for WIA
  - SD.3 objectives and desired outputs

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Concurrence

- General points of concurrence
  - Maintain consistency with Chemical and Biological models as feasible
    - No modeling of medical intervention
    - No inclusion of battle stress cases
- General modeling concept – human response can be estimated using specified severity levels as occur on injury profiles
  - Nuclear irradiation progressions concurred to with changes
    - Will review additional data, specifically as it applies to Lower GI
  - Blast progressions (Respiratory as dominant) concurred to with changes
  - Thermal progressions concurred to with changes

Concurrence (cont'd)

- Dose/insult ranges with corrections
  - Radiation: <1.25 NOE, first observable band 1.25—3 Gy
  - Blast: no corrections
  - Thermal (Thermal Flash Burn Ranges): final band: ≥ 31%; 21-30% band includes 10% fatalities
- Symptoms systems
  - Blast: Respiratory as dominant (neglect other systems)
  - Thermal:
    - Neglect Upper GI system for all ranges
    - Neglect Immune system for ≥ 31% range
- Symptoms descriptions
  - Remove "Signs" from descriptors
  - Modify Immune System symptoms as described
  - Modify Skin (Thermal) System symptoms as described
  - Add "possible micro-hemorrhaging" to Cardiovascular System level 2

Concurrence (cont'd)

- Human response: radiation
  - Calculate time-to-death as a function of dose
    - Utilize IDP Methodology (Green line)
- Human response: blast
  - Consider dynamic effects (prone-tumbling) in addition to static overpressure effects for estimation of KIA
    - Utilize Drake Methodology (proposed)
- Human response: thermal
  - No additional areas
- Human response: combined
  - Methodology for combining R-B-T injury profiles

Concurrence (cont'd)

- Casualty Criteria
  - Recommended Casualty Definitions
  - Recommendations for WIA with R-B-T severity
  - R-B-T injury profiles described/graphed in annex to AMedP-8(c)
  - R-B-T system injury progressions described/graphed in TRM

Additional Tasks

- Participants –
  - Provide supporting documentation, studies, & references as available
  - Review Irradiation (Lower GI and Immune particularly), Blast, and Thermal injury progressions with National SMEs (22 July)
- OTSG/IDA –
  - Incorporate comments as provided for Read-aheads
  - Prepare updated injury progressions and profiles for National reviews
    - Send updated profiles out for review (8 July)
  - Take Thermal (Flash Burn) injury progressions to ISR/USRAIR for review
  - Incorporate National comments as provided for updated profiles

Additional Tasks (cont'd)

- OTSG/IDA (cont'd) –
  - Update the dose/insult ranges as discussed
  - Update the system symptom severity descriptions as discussed
  - Update the injury progressions and profiles as noted

Additional Tasks (cont'd)

- OTSG/IDA (cont'd) –
  - Notations to be added:
    - This document is for use for human response modeling and casualty estimation purposes only; it is not to be used for operational, logistical, or diagnostic purposes.
    - Purpose: Revise the purpose statement to include "casualties *uniquely* occurring"
    - Severity definitions:
      - These severity definitions are to be used for modeling purposes only; they are not to be used for operational classification of personnel in real-world situations
      - Symptoms descriptions proposed for use in AMedP-8(C) are not the same as those used in AMedP-8(A)
    - Insult description: Describe thermal fluence as "radiant thermal energy" for clarity
    - Correct skin thickness (from nm to um)
    - Limitations (Limitations section must be included up front)
      - The physiological systems considered in the modeling of injury progression are not all inclusive and not the sole potential mechanisms for injury; certain additional casualties may occur due to other injuries or injuries to other physiological systems.
      - Eye injuries are not included in the physiological systems modeled

AMedP-8(C) Study Timeline

- SD.3 (Describe algorithms and required parameters for human response models)
  - Custodial Meetings--review technical aspects of modeling human response with national Subject Matter Experts
    - 21-22 April 2008, Chemical agents (Munich, in conjunction with German Medical Chemical Conference)
    - 8-9 May 2008, Biological agents (San Lorenzo de El Escorial, in conjunction with 21st BioMedAC)
    - **23-27 June 2008, Nuclear effects & Radiological agents (Albuquerque, New Mexico)**
  - September 2008, "Virtual Custodial Meeting" for final pre-coordination review of CBRN casualty estimation (by correspondence)
  - November 2008, Publish SD.3 for review
  - February 2009, Custodial Meeting in conjunction with CBRNMedWG Meeting to adjudicate SD.3 comments and discuss input to NATO conventional casualty estimation tools (Brussels)

Questions?

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14. ABSTRACT

In June 2008, NATO subject matter experts met in Albuquerque, New Mexico, United States of America to discuss an approach to modeling human response and casualty estimation for incorporation into NATO Allied Medical Publication 8, *NATO Planning Guide for the Estimation of CBRN Casualties*. The purpose of this conference was to review the proposed human response model for estimating casualties resulting from exposure to nuclear effects, focusing in particular on severity definitions and the injury profiles for whole-body radiation dose and blast and thermal insults. During the conference, participants reached consensus on the nuclear human response model and the injury profiles for use in the document. The presentations and consensus points reached during the NATO Nuclear Human Response Subject Matter Expert Review Conference are summarized herein. This conference was sponsored by the US Army Office of the Surgeon General (OTSG).

15. SUBJECT TERMS

Modeling, human response, casualty estimation, nuclear, nuclear warfare, whole body radiation, radiation, blast, thermal, static blast overpressure, burn surface area, tertiary blast, combined nuclear effects, dynamic blast, irradiation

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